# Beyond Lean Manufacturing: the Productivity, Innovator's and Proactivity Dilemmas resolved.

A thesis submitted in fulfilment of the requirements for the Degree of Doctor of Philosophy

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**Declaration.**

The candidate signs a declaration certifying that:

a) except where due acknowledgement has been made, the work is that of the candidate alone.

b) the work has not been submitted previously, in whole or in part, to qualify for any other academic award;

c) the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program;

d) any editorial work, paid or unpaid, carried out by a third party is acknowledged;

e) ethics procedures and guidelines have been followed.

Signed: Alexander Vladimiravich Shamshurin ..

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This work is dedicated to the memory of my father Vladimir Illyich Shamshurin.

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# ABSTRACT

This dissertation provides direction for the management of exploration in an exploitative context by specifying the theory for a universal model of ambidexterity. Research in ambidexterity centres upon how exploration for the future and exploitation of the present can be achieved simultaneously through the management of innovation. Ambidexterity theory strives to resolve the Productivity and Innovator's Dilemmas, which assert collectively that exploration is inherently antagonistic to exploitation. The Productivity Dilemma asserts that the organisation and routinisation of processes required for efficient exploitation are incompatible with the flexibility required for exploration. The Innovator's Dilemma asserts that a focus on exploitation through incremental innovation in a stable environment inhibits exploratory innovation, which leaves an enterprise vulnerable to obsolescence from disruptive innovation. Whilst ambidexterity is an issue that dominates in the literature for innovation management and manufacturing systems, the theory for a unifying framework that reconciles competing approaches is not reported. Moreover, the methods and tools for the execution of ambidexterity require significant development.

The candidate contends in this dissertation that the ambidexterity issue is epitomised by Toyota's announcement in 2007 of its intent to implement transformational innovation (*kakushin*) in a controlled and historically consistent environment. Toyota is known for its system of "Lean Manufacturing", which is regarded widely for its high productivity and institutionalised continuous improvement (*kaizen*).

This dissertation gives a new perspective on Lean Manufacturing by its critical evaluation through an interdisciplinary framework of innovation, economic and behavioural criteria. Lean Manufacturing is de-constructed and shown to be a systematic evolution from ordered antecedents, which represent an exploration-exploitation continuum that can be used to reconcile the competing approaches towards ambidexterity. Furthermore, a third dilemma is presented by this dissertation, which acts in concert with the Productivity and Innovator's Dilemmas and is named by the candidate the "Proactivity Dilemma". The Proactivity Dilemma asserts that exploratory behaviour is perceived increasingly non-proactive as proactivity in exploitation increases.

The candidate uses the insights from their new perspective on Lean Manufacturing to specify the theory for a universal model of ambidexterity. The candidate's model of ambidexterity encompasses nine core organisational processes, which are categorised by Operations Management, Product Development and Strategic Planning.

This dissertation provides comprehensive direction for the simultaneous management of productivity and innovation, from "boardroom" strategy to "shopfloor" tactics.

# CHAPTER 1
# SUMMARY

## 1.1 INTRODUCTION.

This chapter introduces the research rationale and objectives of this dissertation. The chapter concludes with a map of the strategic argument for the execution of this dissertation.

## 1.2 RESEARCH RATIONALE.

### Automotive industry and manufacturing.

A significant outcome from the automotive industry is its contribution to the advancement of manufacturing systems. Despite operating in aggressive markets, the modern industry has managed to prosper. During economic downturn, it is regarded as the first industry to suffer a downturn and last to recover. The automotive industry can provide a barometer for economic progress because the purchase of a new automobile is delayed easily until real or perceived economic uplift occurs. The complexity of automobiles and the high expectations of its consumers demand increasingly productive manufacturing systems from their producers, which has resulted in the emergence of efficient and integrated supply chains. Because of the automobile industry's deep roots in the development of manufacturing systems and supply chains, the automotive industry is considered to guide the general direction of manufacturing.

Whilst the fundamental principles of the automotive industry's manufacturing systems may have been practiced earlier[1], it was the automotive industry that symbolised and defined them. Mass production is a household term and is associated readily with Henry Ford and his Model T automobile. Increasingly, the system of "lean" manufacturing is being recognised and associated with Toyota. Lean manufacturing was innovated by Toyota and is responsible for Toyota's elevation to the position of the automotive industry's leader in sales and profitability[2] (Stewart and Raman, 2007). Toyota's elevation to market leadership has prompted near universal credence of lean manufacturing throughout the automotive industry, to the point where lean manufacturing has displaced effectively mass production (Krafcik, 1988; Womack *et al*., 1991; Holweg, 2007). *E.g.* in Australia, lean manufacturing is endorsed by Automotive Supplier Excellence Australia (ASEA, 2008). The success of Toyota's manufacturing system has gained attention outside of the automobile industry, which has resulted in significant overspill to general manufacturing. Major economic regions where overspill has occurred include U.K., Japan, Europe, U.S.A. and China (EEF, 2001; Hines

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[1] Mass production it attributed to the 1320 Venetian arsenal factory (Quintessence, 2009, p. 161). Hall argues that the antecedents of lean manufacturing can be found in the way Romans built warships and the system of continuous improvement used by the Roman army (Hall, 1983, cited in Holweg, 2007, p. 431).

[2] Toyota announced its first annual operating loss in its 71 year history in 2009 in the wake of the global financial crisis (Porter, 2009). Whilst the 2008 global financial crisis affected Toyota's profitability, the second largest car producer GM accrued an $U.S. 85 Billion debt and surrendered effectively to state ownership. Toyota remained in surplus.

*et al*., 2004; Taj, 2007). Accordingly, there has been significant adoption of lean manufacturing by non-automotive manufacturers in Australia (Sohal and Egglestone, 1994; Commonwealth of Australia, 2008). Moreover, the principles of lean manufacturing are being applied increasingly in service organisations (Womack and Jones, 2005; Hines *et al*., 2008).

There is great importance in testing issues relating to lean manufacturing because it dominates world manufacturing.

**Lean manufacturing.**

Lean manufacturing (LM) was conceived as a novel means of cost reduction (Ohno, 1988). LM's primary features are waste elimination and the organisation of production around a demand-pull flow. Waste elimination attacks the residual waste inherent in mass production (Feigenbaum, 1956). Demand-pull flow means manufacturing only when items are required. In essence, LM aspires to a state of total efficiency. The efficiency that Toyota generated as a relatively insignificant late market entrant allowed it to compete successfully against incumbent mass production giants. Demand-pull was implemented initially in production operations and was then extended to product development, which formed a complete customer-pull business model (Cusumano, 1988, Holweg, 2007; Osono *et al*., 2008). Thus, aligned with manufacturing products only when required (demand-pull), product design will design products only to satisfy customer needs (customer-pull) (Hines *et. al*., 2008). Toyota facilitates its customer-pull approach through the empowerment of its employees to engage in continuous incremental improvement (called *kaizen*), which allows enterprise-wide accumulation of diminutive innovations. Toyota contends that the continuous accumulation of incremental improvements is a more successful approach to innovation in the long-run than a reliance on discontinuous or intermittent step innovations (Ohno, 1988). Toyota's customer-first orientation and *kaizen* approach to innovation and has won devotees who champion lean ideology as a sustainable business model (*e.g.* Womack and Jones, 1991; Liker, 2004; Hines *et al*., 2008; Osono *et al*., 2008).

The candidate expects to show that Toyota can be upheld as an exemplar of the customer-pulled continuous incremental improvement approach to innovation (*kaizen*).

**Contemporary Toyota.**

Whilst *kaizen* is entrenched in Toyota, there are disparate shifts in the contemporary Toyota literature and published discourse. Toyota President[3] Watanabe declared in 2007: "15 years ago I would have said that as long as we have enough people, Toyota could achieve its goals by *kaizen* (alone). However in today's world, change can be produced by *kaizen*, but it may also need to brought about by *kakushin*. When the rate of change is too slow, we have no choice but to resort to

[3] Watanabe was replaced by Akio Toyoda in June 2009 who is a grandson of Toyota founder Kiichiro Toyoda. Watanabe stepped down to vice-chairman after achieving unprecedented growth and financial surplus, which allowed the younger Toyoda who was groomed for presidency to lead Toyota in its next historical chapter (Hassall, 2009).

drastic changes or reform" (Stewart and Raman, 2007, p. 81). The candidate contends that *kakushin* is disparate in two ways. Firstly, because *kakushin* is new to the Toyota literature and published discourse and amongst industry observers *kakushin* is perceived as a radical new approach to innovation by Toyota (Chappell, 2007; Treece, 2006, 2007a, 2007b). Indeed, Toyota is renowned for its conservative mindset and historical consistency in the *kaizen* approach to innovation (Womack *et al*., 1991; Liker, 2004). Secondly, because of *kakushin's* schism with *kaizen*. Watanabe explains: "The two have different focuses; there's continuous change in *kaizen* and there's discontinuity in *kakushin*" (Stewart and Raman, 2007, p. 82). The candidate argues that according to innovation theory *kakushin* resonates with disruptive change and the technology-push approach to innovation (*e.g.* Utterback and Abernathy, 1975; Dosi, 1988; Anderson and Tushman, 1990; Bower and Christensen, 1995; Utterback and Acee, 2005; Roberts, 2007; Dosi and Grazzi, 2010). The significance of the relationship between *kakushin* and the technology-push approach to innovation is that technology-push is opposed directly to customer-pull. Technology-push changes consumer behaviour and installs new needs through disruptive innovation. Customer-pull reacts to existing consumer needs and satisfies them through continuous incremental improvement.

The candidate argues that the new Toyota innovation approach of *kakushin* (technology-pushed disruptive change) forms a dichotomy with *kaizen* (customer-pulled continuous incremental improvement).

**The productivity and innovator's dilemmas.**

The contemporary literature for innovation management and manufacturing systems abounds with calls for research into the issue of contextual operations design, which moves beyond a one-size-fits-all approach to innovation and manufacturing (*e.g.* Teece, 2007; Nair and Boulton, 2008; Pham *et al*., 2008; Sousa and Voss, 2008; Taylor and Taylor 2008; Cetindamar *et al*., 2009; Magnusson *et al*., 2009). The centrepiece in the issue of contextual operations design is the need for a conclusive resolution of the productivity and innovator's dilemmas. The productivity dilemma asserts that the routinisation required for efficient production flow is incompatible with the flexibility required for technology-pushed innovation (Abernathy, 1978). The innovator's dilemma asserts that proficiency in continuous incremental improvement inhibits technology-pushed innovation and leaves an enterprise vulnerable to disruptive innovation, which originates from outside of the enterprise (Christensen, 1997). The productivity and innovator's dilemmas assert collectively that efficient enterprises develop specific routines and attitudes, which gravitate towards a steady-state and reject anything but incremental adjustment of the *status quo* (March, 1991; Levinthal and March, 1993; Zollo and Winter, 2002; Benner and Tushman, 2003; Bessant *et al*., 2005; Lavie and Rosenkopf, 2006; Takeda, 2006; Hendricks *et al*., 2007; Molina *et al*., 2007; Teece, 2007; Peng *et al*., 2008; Sroufe and Kurkovic, 2008; Adler *et al*., 2009; Bendoly *et al*., 2009; Jayawarna and Holt, 2009; Lopez-Mielgo *et al*., 2009).

The candidate expects to show that lean manufacturing gravitates towards a steady-state because variation is disruptive intrinsically to customer-pulled production flow.

**Ambidexterity.**

The concept of ambidexterity is proposed as a potential solution to the productivity and innovator's dilemmas (Gupta *et al*., 2006; O'Reilly III and Tushman, 2008; Raisch and Birkinshaw, 2008; Adler *et al*., 2009). The theory for ambidexterity addresses the simultaneous management of **exploitation** of the *status quo* with **exploration** for the future. Ambidexterity theory translates the productivity and innovator's dilemma into terms of exploration and exploitation. **Exploration** is characterised by the technology-push approach to innovation, which strives for the development of competency destroying technologies. **Exploitation** represents the customer-pull approach to innovation, which focuses on the enhancement of an enterprise's competencies through best-practice operational excellence (Utterback and Abernathy, 1975; Dosi, 1982; Clark, 1985; Dosi, 1988; Anderson and Tushman, 1990; Bower and Christensen, 1995; Porter, 1996; Benner and Tushman, 2003; Fagiolo and Dosi, 2003; Justman, 2004; Utterback and Acee, 2005; Teece, 2008; Grebel, 2009).

The candidate expects to show that Toyota's *kaizen* approach to innovation exemplifies exploitation.

**External disruption.**

The fundamental argument for an ambidextrous approach to innovation is that the exploitation of technological paradigms through efficiency is limited because technological paradigms become obsolete and displaced by new paradigms. Technological paradigms are considered to follow ordered trajectories that are disrupted externally through competency destroying technology-push innovations (Dosi, 1988). The exploration of new paradigms is required in order to offset the diminishing returns and obsolescence of aging paradigms. However, a key issue for enterprises that concentrate on exploitation is that exploitative capabilities and structures are different fundamentally to those required for exploration (March, 1991; Benner and Tushman 2003; Nijssen *et al*., 2005; Prajogo and Sohal, 2006; Choo *et al*., 2007; Fortanier *et al*., 2007; O'Reilly III and Tushman, 2008; Peng *et al*., 2008; Anand *et al*., 2009; de Visser *et al*., 2010; Parker and Collins, 2010). An outcome from exploitative capabilities and structures is that exploitative enterprises are positioned poorly to explore new technological pardigms[4], which makes them vulnerable to external disruption.

[4] The candidate suggests that evidence for a shift by Toyota towards exploration outside of the existing automobile paradigm can be found in the Toyota narrative, which may be argued to reflect *kakushin*. Toyota's 2020 Global Vision statement that was released after Watanabe's announcement of *kakushin* reframed Toyota's core business from automobiles to "mobility technology" (Toyota Motor Corporation, Public Affairs Division, 2008, p. 6). Furthermore, there was a vigorous affirmation of exploration in domains that are non-traditional to the contemporary automobile paradigm. The candidate suggests that Toyota's 2020 vision may reflect BYD (Build Your Dream) Auto, which declared its intent to become the biggest Chinese automobile manufacturer by 2015 and world biggest by 2025 (BYD Auto, 2010). BYD auto was a former producer of rechargeable batteries for mobile phones that believed it could mass produce economically an automobile equivalent (Oliver, 2008). Furthermore, BYD auto's battery technology will be complemented by an extensive network of rapid, automated, battery exchange points. Moreover, with significant government backing in infrastructure, and green power provision (Dateline, 2009).

*Table 1: Summary of key associations in the Candidate's research rationale.*

| | TECHNOLOGY-PUSH | CUSTOMER-PULL |
|---|---|---|
| Productivity dilemma (Abernathy, 1978). | Flexible. | Efficient. |
| Innovator's dilemma (Christensen, 1997). | Causes transformational disruption and intermittent radical innovation. | Results in continuous incremental improvement. |
| Ambidexterity (*e.g.* March, 1991; Gupta *et al.*, 2006; Adler *et al.*, 2009). | Exploration (for future). | Exploitation (of *status quo*). |
| Innovation, economic and behavioural theories (*e.g.* Dosi, 1982; Dosi, 1988; Clark 1985; Levinthal and March, 1993; Porter, 1996; Benner and Tushman, 2003; Siggelkow and Rivkin, 2006; Teece, 2008; Grebel 2009; Parker and Collins, 2010). | Causes volatile disruption and obsolescence.<br><br>Creates novel technology, destroying existing competencies.<br><br>Exogenous independence to existing paradigms.<br><br>Proactive. | Gravitates to steady-state operational excellence.<br><br>Employs technology enhancement, building existing competencies.<br><br>Endogenous market growth within existing paradigms.<br><br>Reactive. |
| Toyota (Stewart and Raman, 2007). | ***Kakushin*.** Signifies new, disparate practice and exploration beyond existing automobile paradigm. | ***Kaizen*.** Maintains historically consistent practice and exploitation of existing automobile paradigm. |

### 1.3 RESEARCH OBJECTIVES.

Whilst ambidexterity is an important theme in the contemporary literature for innovation management and manufacturing systems, the candidate observed that the theory for a unifying framework for ambidexterity is not reported. Moreover, the theory for the methods and tools that are used for the execution of ambidexterity require significant development (Abernathy, 1978; Brown and Eisendhardt, 1997; He and Wong, 2004; Gupta *et al.*, 2006; Teece, 2007; Ortt and van der Duin, 2008; Adler *et al.*, 2009; Magnusson *et al.*, 2009).

**Exploration in an exploitative environment.**

The candidate argues that the open issues in ambidexterity theory are epitomised by Toyota's announcement of its intent to implement *kakushin* in a *kaizen* environment. Furthermore, research into how Toyota can reconcile *kakushin* with *kaizen* may provide insight into how the productivity and innovator's dilemmas can be resolved. Moreover, the candidate contends that a third dilemma will emerge in the research, which the candidate has named the **proactivity dilemma**. The proactivity dilemma works in concert with the productivity and innovator's dilemmas and contends that exploratory behaviour is perceived increasingly non-proactive as proactivity in exploitation increases.

**Questions that require resolution.**

The candidate observed that the theory for lean manufacturing has never been evaluated through an interdisciplinary approach of innovation, economic and behavioural criteria, which the candidate contends can present a new perspective on lean manufacturing. The candidate expects to show that lean manufacturing can be explained theoretically as a systematic evolution from ordered antecedents and in doing so insight can be gained into the open ambidexterity issues.

The candidate believes that their presentation of a new perspective on lean manufacturing in this dissertation will advance substantially the theory for ambidexterity. The candidate will answer two critical questions. Firstly, how can *kakushin* be reconciled with *kaizen*? Secondly, how can the outcome from the first question be applied towards the advancement of ambidexterity theory? Table 2 defines the objectives of this dissertation.

*Table 2: Research objectives.*

| | OBJECTIVE |
|---|---|
| 1 | Evaluate lean manufacturing through innovation, behavioural and economic criteria. |
| 2 | Apply the insight gained from Objective 1 to the theory for ambidexterity. |
| 3 | Provide theory for the existence of a proactivity dilemma. |

## 1.4 STRATEGIC ARGUMENT MAP.

The chapters in this dissertation are organised around a **strategic argument**, which is mapped in Table 3. Sections within this dissertation that are barred represent critical markers that are aligned with the development of the strategic argument.

*Table 3: The Strategic Argument Map.*

| | THE STRATEGIC ARGUMENT |
|---|---|
| **Chapter 1** | Present research rationale.<br>Outcome: Research objectives and strategic argument map. |
| **Chapter 2** | Survey literature.<br>Outcome: Justification of research rationale. |
| **Chapter 3** | Outline the approach to evaluating lean manufacturing.<br>Outcome: Formation of a relationship between lean manufacturing and its predecessors. |
| **Chapter 4** | Detail established theory and develop a new perspective on lean manufacturing.<br>Outcome: Theory that contains three dominant manufacturing paradigms that evolved in a systematic manner in which lean manufacturing is equal to the other two paradigms. |
| **Chapter 5** | Insert the practices of lean manufacturing into the theory.<br>Outcome: Evaluation of the result against the theory. |
| **Chapter 6** | Form hypotheses based on the evaluation of lean manufacturing against the theory.<br>Outcome: Testing of these hypotheses and evaluation against existing strategic, innovation and economic models. |
| **Chapter 7** | Develop the theory to transpose the findings (of hypotheses testing) to processes other than manufacturing (quality management, supply chain management, product development *etc.*).<br>Outcome: Formed theory for the transposition of findings. |
| **Chapter 8** | Transpose findings to other processes.<br>Test compatibility of the transpositions as a complete unit against a systems analysis tool.<br>Outcome: Improvement in the theory for ambidexterity. |
| **Chapter 9** | Conclusion.<br>Outcome: Evaluation of achievement against objectives, original contribution and future research |

## 1.5 SUMMARY.

This chapter introduced the research rationale and objectives of this dissertation. The candidate argued in the research rationale that Toyota's announcement in 2007 to implement transformational innovation (*kakushin*) in an environment that is dominated by incremental improvement (*kaizen*) epitomises a contemporary research issue in the literature for innovation and operations management. A key issue that requires resolution is the theory for an ambidexterity model and the methods and tools for its application. Ambidexterity theory is founded on the principles of the productivity and innovator's dilemmas, which argue collectively that transformational innovation in an entrenched environment of incremental improvement is incompatible inherently. Transformational innovation is regarded in ambidexterity theory as exploration and incremental improvement is regarded as exploitation. The objective of ambidexterity theory is to provide direction into how the conflicting innovation approaches of exploration and exploitation can be managed.

The candidate made three key contentions in the research rationale. Firstly, the evaluation of Toyota's system of lean manufacturing through an interdisciplinary approach of innovation, behavioural and economic criteria will present a new perspective on lean manufacturing. Secondly, the candidate expects to show that lean manufacturing can be explained theoretically as a systematic evolution from ordered antecedents and in doing so insight can be gained into the open ambidexterity issue. Thirdly, a proactivity dilemma will emerge in the research that works in concert with the productivity and innovator's dilemmas. The proactivity dilemma contends that exploratory behaviour is perceived increasingly non-proactive as proactivity in exploitation increases. Critical questions the candidate will answer are how can *kakushin* be reconciled with *kaizen* and how can the insight gained advance the theory for the open ambidexterity issue.

The chapter concluded with a map of the strategic argument for the execution of this dissertation, which organises the chapters in this dissertation and defines their outcomes.

# CHAPTER 2
# LITERATURE SURVEY

## 2.1 INTRODUCTION.

This chapter establishes the state-of-the-art in Toyota innovation theory through a literature survey by the candidate. A survey is instituted according to the strategy in Table 3 of this dissertation in order to determine the degree of academic reconciliation between *kakushin* and *kaizen* in the literature and to identify theory that could be used to bridge potential gaps. Selection and ranking criteria are developed and applied by the candidate in order to steer the survey. A summary of relevant literature is tabled and cross-referenced against the criteria. Key findings are discussed.

## 2.2 SURVEY STRUCTURE.

The survey is organised in two parts. Part A, establishes the state-of-the-art in Toyota innovation theory *per se*. Part B, establishes the state-of-the-art in the relationship of Toyota innovation theory to interdisciplinary theory.

## 2.3 PART A: STATE-OF-THE-ART IN TOYOTA INNOVATION THEORY.

The candidate contends that Toyota's innovation theory can be encapsulated by its mechanisms of innovation. This dissertation regards a mechanism as a systematic interaction of functional elements, which embody the nature of the innovation generated. Encoded within the mechanism are the structures, routines, attitudes and behaviours that propel it. The prevalence of each mechanism and the degree of academic reconciliation between them can be established by delineating the survey through mechanisms.

### Innovation mechanism nomenclature.

Innovation literature agrees generally on three innovation mechanisms, which comprise a spectrum of generic possibilities. Table 4 shows a synopsis, which was formed by the candidate from key references surveyed.

***Table 4: Innovation mechanism nomenclature.***
***Source: Candidate's design.***

| CODE | INNOVATION MECHANISM | KEY REFERENCES |
|---|---|---|
| T | Transformational disruption. | Utterback and Abernathy (1975); Dosi (1982); Anderson and Tushman (1990); Tidd *et al*. (2001); Schilling (2005); Dosi and Grazzi (2010). |
| R | Radical, intermittent change. | |
| I | Incremental, continuous improvement. | |

### Toyota innovation mechanisms.

The research rationale included two Toyota innovation mechanisms, which can be coded according to the nomenclature. *Kakushin* can be coded T and *kaizen* I. Whilst the rationale highlighted these extremes, all Toyota mechanisms must be considered. The candidate found a third mechanism when preparing the rationale. This mechanism was called *kaikaku* and identified in part with code R (Bicheno, 2002). *Kaikaku* was excluded from the rationale for the following three reasons. Firstly, *kaikaku* was not new to the Toyota literature and published discourse. Secondly, *kaikaku* was found to be effectively absent from the dominant Toyota literature and published discourse. Thirdly, the examples[5] cited did not agree with the scale, scope and frequency implied by *kakushin*. The candidate judged that *kaikaku's* omission avoided distraction from the rationale's central argument without weakening it. The candidate expects that Part A of their survey will corroborate these claims in depth.

**Literature survey method.**

The candidate used a two-step method for the survey's execution. Firstly, the literature is searched through the selection criteria of innovation mechanism, according to *kakushin* (T), *kaikaku* (R) and *kaizen* (I). Secondly, the literature is ranked according to a ranking system devised by the candidate. The ranking system was devised to measure the depth of theory that explained and reconciled the Toyota innovation mechanisms academically. Table 5 explains the ranking system.

***Table 5: Literature ranking system.***
***Source: Candidate's design.***

| RANKING | EXPLANATION |
|---|---|
| 0 | Absent in literature. |
| 1 | Provides description. |
| 2 | Provides guidelines. |
| 3 | Provides framework. |
| 4 | Provides detailed solution. |
| **Bold type.** | Bold type means referenced directly in literature.<br>Normal type means can be assumed. |

**Literature overview.**

The candidate's survey began by identifying the literature central to understanding LM. The survey identified that since LM's adoption outside of Toyota, the literature has reported on several developing phases. Hines *et al*. (2004) researched the issue of LM's development outside of Toyota and captured it as migration through three phases. The first phase was an initial awareness of LM and the second phase was a focus on cost, quality and delivery. The third phase was characterised by a growing importance in approaching LM from the perspective of a total enterprise. Later research by Hines *et al*. (2008) confirmed that the enterprise approach was now embedded in contemporary research, but noted that LM's adoption and literature is often dominated by its tools and methods. Hines *et al*. (2008) warned that a focus on tools and methods can obscure the theory behind LM. The

[5] *E.g.* Liker (2004) described the sudden inception of the subsidiary Lexus brand. Bicheno (2002) related *kaikaku* to "blitzes" on existing processes, aimed to improve dramatically productivity. Whilst these may be regarded as significant events, the dissertation expects to show they are not transformational.

candidate resolved that it was important to capture LM's true essence. The candidate's survey focussed firstly on the establishment of a baseline of reliable literature, which was accepted as being foundational and where possible, sanctioned by Toyota.

***Baseline literature for Lean Manufacturing and kaizen theory.***

Holweg (2007) compiled a comprehensive timeline of key events and literature in a paper dedicated to LM's genealogy. The candidate used Holweg (2007) as a guide to establish a baseline of reliable literature for LM and *kaizen* theory. The most important was a text by Toyota employee Ohno (1988), which written to explain LM. Ohno (1988) provided what is accepted as unblemished theory, because of his fundamental role in the design and implementation of LM at Toyota. Here, Ohno explained why LM was conceived and how it contrasted with Henry Ford's theory of mass production (MP). Ohno made substantial reference to Ford's (1926) foundation text, which written from a MP perspective. Ford's (1926) text was a key motivator for LM and was selected as a fundamental adjunct to Ohno, in that it too could be regarded as providing unblemished theory. Ohno's and Ford's texts allowed this dissertation to establish continuity between MP and LM and the contextual conditions in which they were conceived. Whilst the fundamental continuity between LM and MP had been made, the candidate believed that more detail was required. Holweg (2007) regarded Womack *et al*'s (1991) text as a *tour de force* in the recognition of LM outside of Toyota. A review of Womack *et al*. (1991) by the candidate found compelling data about LM's performance against MP and a framework for LM's approach to innovation. Additional insights were found in papers by Krafcik and Cusumano, which were also consistent with Holweg's (2007) genealogy. Krafcik's (1988) paper provided a basis for delineating LM from MP as paradigms in a pure sense. Cusumano (1988) provided insights into the differences between the dominant innovation mechanisms of MP and LM. A significant finding in Cusumano's (1988) paper was a clear association of *kaizen* with LM and radical innovation with MP. Cusumano argued that MP had an inherent propensity to facilitate radical innovation and not *kaizen*. The candidate regarded this as an important result, because it could be used to help explain the contextual conditions in which *kaikaku* and *kakushin* are effective. The candidate's survey revealed an additional paper that could be used to augment the contextual conditions from which LM emerged, which was not present in Holweg's (2007) genealogy. The dissertation included the landmark paper by Feigenbaum (1956) in the baseline of literature for this dissertation. Feigenbaum (1956) introduced the concept of total quality control (TQC), which is accepted widely as a great step forward in the field of quality management. The candidate observed that Feigenbaum's (1956) paper coincided with the emergence of LM and had striking similarity between Feigenbaum's justification for TQC and Ohno's justification for LM. Whilst Feigenbaum was unaware of LM, their paper is regarded by the candidate to be pivotal to this dissertation. Here, the candidate expects to show that Feigenbaum's (1956) underlying concepts can be developed and used to provide fresh insights into LM and the productivity dilemma.

The candidate believed that the aforementioned literature provided a reliable baseline of literature for the following three reasons. Firstly, it provided a true account of LM and *kaizen* theory. Secondly, it explained fundamentally the continuity between LM and MP and the contextual conditions from which they emerged. The continuity between LM and MP is important, because the literature reports that LM is understood effectively within the context of MP as its antecedent (Cusumano, 1988; Krafcik, 1988; Ohno, 1988; Womack *et al*., 1991; Holweg, 2007). Thirdly, the baseline literature provided a framework that could be used to address potential gaps in the academic reconciliation of *kakushin* with *kaizen* and the formation of an ambidexterity model.

***Technical detail.***

The candidate believed that whilst a reliable baseline had been established, more details of LM and *kaizen* needed to be provided. Monden's (1994) study of Toyota was also presented in Holweg's (2007) genealogy. The candidate reviewed Monden (1994) and regarded it as the most important technical account of LM. Monden was a Japanese university Professor and the first outsider to be endorsed by Toyota to study its systems in detail. Here, a detailed and accurate analysis of LM was provided. Shingo's (1981) research into LM was also presented in Holweg (2007). The candidate reviewed Shingo (1981) and regarded it as a complement to Monden (1994). Shingo was a consultant to Toyota who developed key elements of LM. Whilst Monden's (1994) strength was in detailed systems analysis, Shingo (1981) contributed detail of operational tactics and related them directly to Toyota's mindset during LM's emergence. Additional detail was contributed by Takeda (2006), who explained strongly the relationship between *kaizen* and LM operational systems from a more recent period. The candidate concluded their survey on technical detail after locating a final important text by Imai (1986), which expounded fully the academic relationship between LM and *kaizen*. Imai (1986) was regarded by the candidate to be important to this dissertation because of its direct historical influence on Toyota and exposition of *kaizen* as a mechanism.

***Kakushin, kaikaku* and *kaizen.***

The candidate directed their survey towards the specific issue of how Toyota's innovation mechanisms of *kakushin* and *kaikaku* are reconciled academically with *kaizen* in the literature and published Toyota discourse. The candidate believes that the only known literature in which Toyota's three innovation mechanisms co-exist is Stewart and Raman's (2007) interview with Toyota President Watanabe. Here, the candidate noted that a description was provided of the three innovation mechanisms but no theory of how they are reconciled within Toyota.

***Kakushin and the other Toyota innovation mechanisms.***

The candidate then directed the survey towards the general issue of how *kakushin* was reconciled in the literature and published Toyota discourse. The candidate's survey revealed that direct scholarly references to *kakushin* are rare. Kondou (2003) provided a theoretical account of the relevance of *kakushin* in the formation of industrial eras and provided some theory into its relationship to *kaizen*. Here, *kakushin* represented an accumulation of *kaizen* that is punctuated by wholesale innovation, which resulted in a new era. Kondou (2003) did not reference Toyota but did provide insight into how *kakushin* was perceived generally in Japan. A specifically scholarly reference to Toyota was found in a paper on ambidexterity by authors Adler *et al*., which presented contemporary perspectives of the productivity dilemma. Adler *et al*. (2009) recognised the development of *kakushin* at Toyota and related it to *kaizen*. Here, it was argued that whilst *kakushin* and *kaizen* have contrasting scales, they represent different outputs from the same innovation process. Whilst Adler *et al*. (2009) referenced *kakushin* and *kaizen*, they did not reference *kaikaku*. Here, the candidate assumed that *kaikaku* may be have been implied within *kakushin* as being a lesser degree of *kakushin*. The candidate noted that Adler *et al's* (2009) argument was founded in the theory of dedicated Toyota ambidexterity scholars Osono *et al*. (2008) and Takeuchi *et al*. (2008), who are accepted as the leading scholars into how Toyota reconciles its innovation mechanisms. The candidate reviewed Osono *et al*. (2008) and Takeuchi *et al*. (2008) and regarded them to be significant to this dissertation. They provided a theoretical framework on how Toyota manages intermittent radical change with continuous improvement, which was based on a 6 year study of Toyota with privileged access. Here, Osono *et al*. (2008) and Takeuchi *et al*. (2008) reported on the reconciliation of *kaikaku* with *kaizen*. The candidate noted that *kakushin* was absent in Osono *et al*. (2008) and Takeuchi *et al*. (2008) and made two conclusions. Firstly, that Osono *et al*. (2008) and Takeuchi *et al*. (2008) represent the state-of-the-art in the reconciliation of *kaikaku* with *kaizen*. Secondly, that Adler *et al*. (2009) represent a recognition of *kakushin* as an elevated degree of *kaikaku* and a step academically towards its reconciliation.

The candidate had surveyed *kakushin* in depth and then considered other literary sources. Several news articles provided information on the perception of *kakushin* amongst industry observers, which were in response to Stewart and Raman's (2007). Whilst these may reside in the lower echelons of literature, they hold credibility in the sense that as the automotive industry leader, there is hawkish observation of singular developments at Toyota. Two articles by Treece, ascribed *kakushin* to a disparate shift in Toyota thinking (Treece, 2007a; 2007b). The candidate also surveyed how Toyota portrayed itself publically after Stewart and Raman's (2007) interview. The most important literature was Toyota's official public handbook, which outlined its latest developments and strategic objectives (Toyota Motor Corporation, Public Affairs Division, 2008). No direct reference to *kakushin* was found in the handbook and it was reasoned by the candidate that this may be for the protection of competitive details. However, the handbook had two new outcomes, which the candidate contends are a reflection of Toyota's recent emphasis on *kakushin*. Firstly, Toyota emphasised an vigorous approach to the exploration of future possibilities and an expansion in the scope of where opportunities may be found. The candidate notes this to be a significant departure from *kaizen* in that there is a fundamental exploratory focus, which moves beyond the existing automobile paradigm[6]. Secondly, there is a recognition of a cyclic nature to innovation in accordance with Kondou (2003), which recognises that exploratory innovation can create new industries.

***Kaikaku and the other Toyota innovation mechanisms.***

The candidate then directed their survey towards the general issue of how *kaikaku* was reconciled in the literature and published Toyota discourse. The most important theoretical account of *kaikaku* was by Bicheno (2002), which defined in depth the approaches and outcomes of *kaikaku* and *kaizen*. The candidate noted two outcomes from Bicheno's research, which impacted this dissertation. Firstly, Bicheno did not address *kakushin*. Secondly, Bicheno did not reconcile the application of the Toyota innovation mechanisms of *kaikaku* and *kaizen*. Bicheno (2002, p. 183) stated: "Although this paper has set out a few pointers, much research is needed to understand the best strategies for each (*kaikaku* and *kaizen*)". A partial reconciliation between *kaikaku* and *kaizen* from the perspective of strategy was found in Imai's (1986) text, which provided a temporal relationship. Imai explained that *kaikaku* preceded and formed a platform for *kaizen*. Imai's temporal relationship was supported in more recent sources. Jones (2005) accepted it as an established concept in a management article. Jone's article held credibility, in that they were co-author in Womack *et als*' (1991) text and accepted as a LM researcher.

The candidate had surveyed in depth *kaikaku's* reconciliation with *kakushin* and *kaizen* and then made several conclusions. Firstly, *kaikaku* identified firmly with intermittent radical innovation (code R) and similar to *kaizen*, acted **within** an existing paradigm (Imai, 1986; Bicheno, 2002; Kondou, 2003; Jones, 2006). *Kaikaku* is delineated from *kakushin* in that *kakushin* acts **outside** of an existing paradigm. Secondly, *kaikaku's* academic reconciliation with *kakushin* and *kaizen* is complete partially.

***Towards a reconciled fully ambidexterity model.***

The candidate then directed the survey towards literature that could be used to develop an ambidexterity model, which may reconcile fully *kakushin*, *kaikaku* and *kaizen*. The analytical framework the candidate intends to use will be presented in Chapter 3 of this dissertation. Chapter 4 will present detailed theory behind it. The following section of the candidate's survey presents the literature selected as being important to developing an ambidexterity model and the reasons why.

The candidate believed that deeper theory must be provided in the practical application of *kaizen*, because of its status as LM pillar. Profound insights into *kaizen's* appropriate contextual conditions

[6] According to Toyota Motor Corporation, Public Affairs Division (2008, p. 5): "the scope of solutions that Toyota offers is expanding from cars to people's living spaces, and the projects and operations to which this expansion gives birth are helping to start new cycles of industry". New research areas include physics, chemistry, biology and medicine (Toyota Motor Corporation, Public Affairs Division, 2008, p. 5).

could be used to contrast *kaikaku* and *kakushin*. The candidate noted that throughout their survey the importance of a supportive culture for *kaizen* was reported frequently (*e.g.* Liker, 2004; Liker and Hoseus 2008). Whilst these provided guidelines for the facilitation of a *kaizen* culture, the candidate believed that further detail needed to be provided. Smadi (2009) provided a comprehensive literature review into the obstacles and benefits of *kaizen* adoption and the attitudes required to precurse a *kaizen* culture. Here, a platform was established. Three further papers provided detailed theory into the specific antecedents to an effective *kaizen* culture. Bessant *et al*. (2001) provided insight into the development of effective *kaizen* behaviour. Harrison (2000) defined key enablers and inhibitors of *kaizen* (Harrison, 2000), which was supplemented by Liker and Choi (2004) who specialised in supply chain development.

The candidate considered that within the literature the objectives of ambidexterity at Toyota were defined insufficiently. The candidate then directed the survey to addressing the issue of what are the specific objectives that must be achieved through ambidexterity. The candidate reasoned that the objectives of ambidexterity in LM could be found in LM's potential limitations. Cooney and Lewis raised the issue of the relationship between LM and non-*kaizen* innovation. Cooney (2002) argued that LM may restrict business opportunities because of an inherent inability to accommodate disruption or significant change. Lewis (2000) argued that competency in LM curtails innovation activity generally, which may inhibit an enterprise's long-term sustainability. Cooney (2002) and Lewis (2000) can be regarded as a reflection of the productivity dilemma in LM, in that they argue for an appropriate balance between efficiency and flexibility in manufacturing. The relationship between flexibility and an enterprise's environment at manufacturing paradigm level was provided by Bartezzesaghi (1999). Here, insights were found into the specific objectives of manufacturing and innovation according to contextual conditions. Enhancement of the relationship between the objectives of manufacturing and innovation according to contextual conditions was found in Browning and Heath (2009). Browning and Heath researched the issues encountered in the development of the Lockheed Martin F-22 aircraft from the application of LM. The dissertation viewed Browning and Heath (2009) as representative of using *kaizen* in a *kaikaku* dominated environment.

The candidate further observed that within the literature, the issue of how value is created in LM is reported to be a key factor in successful LM enterprises. Value creation was considered by the candidate to be of significance to this dissertation, in that it could be used to illuminate the relative dominance of innovation objectives and manufacturing objectives in LM. The survey located two important texts in Hines *et al*. (2004) and Hines *et al*. (2008), which provided a detailed academic account of how value is created in LM. Here, the relationship between product development objectives and manufacturing objectives was defined. Further detail on the relationship between product development objectives and manufacturing objectives was located in Womack and Jones (2003), Womack and Jones (2005) and Morgan and Liker (2006). Here, the Toyota product development system was expounded and related directly to manufacturing.

The candidate believes that the list of cited references in Part A of the survey facilitates the formation of an analytical framework in Chapter 3 of this dissertation.

**Discussion of key findings (Part A).**

A summary of relevant literature and the candidate's rankings are shown in Table 6. Key findings are summarised by the candidate as follows. The three Toyota innovation mechanisms of *kakushin*, *kaikaku* and *kaizen* identified strongly with the selection criteria devised by the candidate and were consistent with the research rationale. *Kakushin* is fresh in the Toyota literature and published discourse. Moreover, with the exception of Stewart and Raman's (2007) interview with Toyota President Watanabe, in which the importance of *kakushin* was stressed, it can be said that *kaizen* has enjoyed historical consistency in its dominance and alignment with LM. However, recent literature has begun to consider deeply *kaizen's* reconciliation with *kaikaku* (Osono *et al.*, 2008; Takeuchi *et al.*, 2008). This has come to the attention of ambidexterity academics Adler *et al*. (2009), who extended the theory provided by Osono *et al*. (2008) and Takeuchi *et al*. (2008) to encompass *kakushin*. The candidate expects this issue will grow in importance as the saliency of *kakushin* emerges.

The candidate concluded that *kaikaku* is an intermediary between *kakushin* and *kaizen* and an important ingredient in fulfilling this dissertation's objectives. Key reasons for this are the inherent relationship of radical innovation, or *kaikaku* with MP (Cusumano, 1988) and *kaikaku's* temporal relationship to *kaizen* as a forerunner (Imai, 1986).

The candidate believes that the academic reconciliation of Toyota's three innovation mechanisms of *kakushin*, *kaikaku* and *kaizen* is in its infancy. Here, the candidate challenges the assertion of Toyota ambidexterity scholars that *kakushin*, *kaikaku* and *kaizen* are different degrees of output from the same process. The candidate expects to show that *kakushin*, *kaikaku* and *kaizen* have different processes fundamentally.

*Table 6: Summary of the Candidate's literature survey on Toyota innovation theory.*

| LITERATURE | DESCRIPTION | T | R | I | COMMENT |
|---|---|---|---|---|---|
| Adler *et al*. (2009). | Toyota ambidexterity. | **1** | 1 | **4** | |
| Bartezzesaghi (1999). | Lean criticism. | 1 | 1 | **3** | |
| Bessant *et al*. (2001). | *Kaizen* theory. | 1 | 1 | **2** | |
| Bicheno (2002). | *Kaizen* and *kaikaku* theory. | 1 | **2** | **3** | |
| Browning and Heath (2009). | *Kaizen* used in other context. | 0 | **1** | **2** | |
| Cooney (2002). | Lean criticism. | 2 | 2 | **2** | |
| Cusumano (1988). | Lean and innovation. | 0 | 2 | **4** | Landmark paper. |
| Feigenbaum (1956). | Lean seedlings. | 1 | 2 | 3 | Landmark paper. |
| Ford (1926). | Lean seedlings. | 1 | 3 | 2 | Landmark book. |
| Harrison (2000). | *Kaizen* antecedents. | 0 | **1** | **3** | |
| Hines *et al*. (2004). | Toyota value creation theory. | 0 | **1** | **4** | |
| Hines *et al*. (2008). | Toyota value creation theory. | 0 | 1 | **4** | |
| Holweg (2007). | Lean evolution. | 0 | 1 | **3** | |
| Imai (1986). | *Kaizen* theory. | 3 | 2 | **4** | |
| Jones (2005). | *Kaikaku* vs. *kaizen*. | 1 | **1** | **1** | Management article only. |
| Kondou (2003). | *Kakushin* theory. | **3** | 1 | **2** | Japanese (non-Toyota) perspective. |
| Krafcik (1988). | Lean evolution. | 1 | 1 | **3** | Landmark paper. |
| Lewis (2000). | Lean criticism. | 0 | 1 | **2** | |
| Liker (2004). | Toyota principles. | 0 | **1** | **3** | Landmark book. |
| Liker and Choi (2004). | Toyota supply chain. | 0 | 0 | **2** | |
| Liker and Hoseus (2008). | Toyota culture. | 0 | 1 | **2** | |
| Monden (1994). | Scholarly account of lean. | 0 | 1 | **4** | First academic study endorsed by Toyota. |
| Morgan and Liker (2006). | Toyota product development. | 0 | 1 | **3** | |
| Ohno (1988). | Internal description of lean. | 0 | 0 | **4** | Landmark book from lean founder. |
| Osono *et al*. (2008). | Toyota ambidexterity. | 0 | 2 | **2** | Toyota endorsed 6 year study. |
| Shingo (1981). | Lean manufacturing theory. | 0 | 0 | **3** | Insights from lean co-founder. |
| Smadi (2009). | *Kaizen* culture. | 1 | **1** | **3** | |
| Stewart and Raman (2007). | Interview with president. | **2** | **1** | **2** | First mention of *kakushin* by Toyota. |
| Takeda (2006). | Lean manufacturing theory. | 0 | 1 | **3** | |
| Takeuchi *et al*. (2008). | Toyota ambidexterity. | 0 | 2 | **2** | Landmark paper. |
| Toyota Motor Corp. (2008). | Toyota overview. | 1 | 0 | **2** | |
| Treece (2007a). | *Kakushin* as industry news. | **1** | 0 | 0 | News article only. |
| Treece (2007b). | *Kakushin* as industry news. | **1** | 0 | 0 | News article only. |
| Womack *et al*. (1991). | Toyota rise to dominance. | 0 | **1** | **3** | Landmark book. |
| Womack and Jones (2003). | Waste elimination theory. | 0 | 1 | **2** | |
| Womack and Jones (2005). | Toyota value creation theory. | 0 | 1 | **2** | |

## 2.4 PART B: STATE-OF-THE-ART IN THE RELATIONSHIP OF TOYOTA INNOVATION THEORY TO INTERDISCIPLINARY THEORY.

Part B establishes the state-of-the-art in the relationship of Toyota innovation theory to interdisciplinary theory. This is required to determine the degree of interdisciplinary theory in Toyota innovation theory and identify theory that could be used to reconcile fully *kakushin*, *kaikaku* and *kaizen* through an ambidexterity model. Selection and ranking criteria are developed and applied by the candidate in order to steer the survey. A summary of selection criteria is shown in Table 7. The logic behind their selection is explained in the literature overview.

*Table 7: Summary of interdisciplinary selection criteria.*

| CODE | CRITERIA | RELATIONSHIP TO TOYOTA INNOVATION THEORY |
|---|---|---|
| | | INNOVATION THEORY |
| **AMB** | Ambidexterity. | Reconciles innovation mechanisms. |
| **DIFF** | Technological diffusion. | Explains process of technological adoption and diffusion. |
| **DOM** | Dominant design. | Explains process of technological maturation and hierarchical design. |
| **STRAT** | Strategy. | Explains strategic imperatives. |
| **TP/CP** | Technology-push/ Customer-pull. | Explains technology-push and customer-pull business models. |
| **TRAJ** | Technological trajectories. | Reconciles technology-push and customer-pull business models. |
| | | ECONOMIC THEORY |
| **SUPP/DEM** | Producer/consumer dynamics. | Explains market dynamics. |
| **UTIL/VAL** | Utility and value. | Explains consumer purchasing decisions. |
| | | BEHAVIOURAL THEORY |
| **DEC** | Decision making. | Explains decision types. |
| **PERS** | Personality types. | Explains personality types. |
| **STRUCT** | Organisational structure. | Explains effects of organisational structure on behaviour. |

**Literature survey method.**

The candidate used a two-step method for the survey's execution. Firstly, the literature from Part A is re-examined according to the selection criteria in Table 7 and ranked according to the ranking system in Table 5. This establishes the depth of interdisciplinary theory in Toyota innovation theory. Secondly, the interdisciplinary literature is surveyed according to the selection criteria in Table 7 and rated according to the ranking system in Table 5. This establishes the capability of interdisciplinary theory to explain academically how Toyota's innovation mechanisms may be reconciled. The literature selected by the candidate's survey will be used for three purposes. Firstly, for the formation of the candidate's analytical framework, which is presented in Chapter 3. Secondly, as the bedrock of the detailed theory for the candidate's analytical framework, which is presented in Chapter 4. Thirdly, for the development of the candidate's ambidexterity model, which will be developed in Chapter 8.

**Literature overview.**

Part A revealed that Toyota innovation theory was centred historically on *kaizen* and that a recent reconciliation with *kakushin* and *kaikaku* was developed partially. A question that requires resolution is how to achieve full reconciliation.

***Contextual conditions.***

The candidate believes that the question of how to reconcile fully the three Toyota mechanisms goes to the heart of a key issue in contemporary innovation and manufacturing research. This issue centres on how a contextual approach to innovation and the design of manufacturing systems can be achieved. Sousa and Voss (2008, p. 698) researched this issue and concluded: "research in maturing operations management best practices has recently began to see a shift in interest from the justification of the value of those practices to the understanding of the contextual conditions under which they are effective". The candidate contends that the establishment of the contextual conditions under which *kakushin*, *kaikaku* and *kaizen* are effective, may provide an avenue to their reconciliation. The candidate further contends that this must be established through an interdisciplinary approach, which is founded on the joint perspectives of innovation, economic and behavioural theories. This contention may be upheld by the following three reasons. Firstly, innovation theory is growing increasingly into a unifying discipline for traditional disciplines such as manufacturing (Linton, 2009). Secondly, the relationship of innovation to economic growth has historical cohesion (Schumpeter, 1939; Dosi, 1982; Dosi 1988; Verspagen 1998, Szirmai and Verspagen, 2003). Thirdly, the candidate expects to show that innovation and economic theories intersect behavioural theory, which can be used to explain the psychological and social processes in innovation, economic decision making and manufacturing systems design.

***Dosi (1982)***.

The candidate drew heavily on a landmark paper by Dosi (1982) in the preparation of the research rationale. Dosi (1982) is regarded by the candidate to be the most important theory in the formation of this dissertation. The significance of Dosi (1982) to this dissertation is that it provides the basis for an analytical framework within which LM can be examined from a new perspective. This in turn, provides an academic explanation of the contextual conditions under which LM is most effective. Dosi provided an all-encompassing model of technological maturation, which was perceived by the candidate to be the representation of an ecosystem of ordered interdisciplinary interaction. Dosi's fundamental contribution to this dissertation was the concept that the evolution of an industry can be explained as the maturation of a technological **paradigm** along a technology **trajectory**. The candidate believes that the evolution of LM can be explained through Dosi's (1982) model.

***Innovation perspective of technological development.***

The candidate observed that a significant feature of Dosi's (1982) model was that it allowed the reconciliation of the opposing innovation approaches of technology-push and customer-pull. Here, a new paradigm is introduced through technology-pushed innovation and evolves into customer-pulled continuous incremental improvement as the paradigm traverses its trajectory. A requirement of this dissertation must be firstly a profound understanding of technology-push and customer-pull theory.

**Technology-push/customer-pull (TP/CP).**

The candidate directed the survey to the technology-push and customer-pull innovation approaches of innovation and their relationship to technological trajectories. The candidate's survey located four papers, which accorded with Dosi's (1982) model and provided significant detail on technology-push and customer-pull innovation. Brem and Voigt (2009) provided detail about the practical application of the two innovation approaches through an extensive literature review. Wonglimpiyarat (2004) provided a theoretical synopsis on the relationship of TP/CP to technological trajectories. Ortt *et al*. (2008) provided detail into the strengths and weaknesses of the two approaches and the contextual conditions in which they are effective. Teece (2008) provided insights into how Dosi's (2008) model could be incorporated into contemporary management practice at a strategic level. The candidate believed that a foundation for TP/CP theory was established and then directed their survey for specific detail on TP/CP application in manufacturing systems. A paper by Hopp and Spearman (2004) was the most important because of their explicit analysis of the strategic and tactical use of TP/CP in manufacturing systems. The candidate noted that in the literature it was reported generally that a significant weakness in the application of technology-push was the issue of accurate technological forecasting. Sandberg (2007) researched this issue and provided a framework for technological forecasting in technology-pushed radical innovation.

The candidate found affirmation throughout the literature for Toyota innovation theory of LM's intimate relationship to customer-pull (Imai, 1986; Ohno, 1988; Monden, 1994; Hines *et al*., 2004; Stewart and Raman, 2007; Hines *et al*., 2008). The candidate observed that there was no recognition of a role for technology-push in LM, with the exception of Imai (1986). Here, it was recognised that technology-push can be used to create a platform for future *kaizen*-based innovation.

**Technological trajectories (TRAJ).**

The candidate then directed the survey to technological trajectories. The candidate observed that Dosi's (1982) model is founded upon four fundamental principles. Firstly, that technological development is characterised by eras. Secondly, there is a shift from product innovation to process innovation. Thirdly, the shift from product to process innovation is aligned with a shift from intermittent radical innovation to continuous incremental innovation. Fourthly, all previous shifts are aligned with a shift from uncertainty to stability. These 4 principles provided the candidate direction for the completion of the TRAJ literature survey.

The candidate's survey found multiple references to technological eras, which were aligned with Dosi's model. Utterback and Abernathy (1975) described the relationship between process evolution and product innovation. They defined two eras, which were characterised by a shift from uncoordinated to systematised manufacturing systems. Here, manufacturing systems became systematised increasingly as product definition grew. The number of eras was increased to three in a later work by Abernathy and Utterback (1978). Here, a transitional era was included, which reflected a fundamental shift in focus from product innovation to process innovation. According to Abernathy and Utterback (1978), major opportunities in product innovation diminished as the product specification firmed. Conversely, process innovation opportunities became more evident and the source of major activity, with both product and process innovation tending to continuous incremental improvement in the long-run. The candidate concluded that the literature agreed generally on three eras, which were captured by (Steele, 1997). Steele described the three eras (in chronological order) as the era of product innovation and engineering domination, the era of process improvement and manufacturing domination and the era of capital intensity and financial domination.

The candidate believed that a foundation was established for the evolution of manufacturing systems and then directed the survey to the evolution of product innovation. The paper by Clark (1985) was identified by the candidate as being second in import to the dissertation to Dosi (1982). Here, a framework for the relationship between product innovation and process development was provided, which encompassed all four fundamental principles of Dosi's (1982) model. Clark (1985) provided three major contributions to this dissertation. Firstly, the candidate could relate the shift in focus from product innovation to process innovation described by Utterback and Abernathy (1975) and Abernathy and Utterback (1978) to an ordered hierarchical pattern in product innovation described by Clark (1985). Here, product innovation migrates from high-order product design concepts to low-order concepts as the product is developed. Accordingly, process innovation intensifies and manufacturing systems become increasingly systematised as the product is developed. Secondly, there is parallel development in the behaviour in consumer purchasing through the consumer's enhanced conceptualisation of the product and performance expectations. Thirdly, the catalyst for the shift in focus from product innovation to process innovation was the formation of a standardised design. Later research by Henderson and Clark (1990) made two advancements to Clarks's (1985) framework. Henderson and Clark (1990) embedded the concepts of architectural innovation and a dominant design. Architectural innovation can be regarded as an intermediary between high-order and low-order design concepts. A dominant design can be regarded as an expansion of Clark's (1985) catalyst of a standardised design, which encompasses the theory that explains its crystallisation and broader consequences.

Whilst Dosi's (1982) model implied a form for technological trajectories, it did not prescribe a specific form. The candidate steered the review to resolve this issue. The candidate observed that the literature agreed generally on the S-curve as being the default form for technological trajectories (*e.g.* Roberts, 2007; Terwiesch and Ulrich, 2008; Talonen and Hakkarainen, 2008). However, it was also noted by the candidate that the S-curve may have aberrations in practice and may not be appropriate in certain applications (*e.g.* Shilling, 2005). The candidate resolved the issue of the appropriateness of using S-curves in this dissertation as the technological trajectory in its analytical framework through Christensen (1992a; 1992b). Christensen researched the issue of S-curve appropriateness and is accepted as an authority on their application. Christensen confirmed that S-curves are representative at both paradigm and architectural levels of technological innovation, but may not be accurate indicators of component progress (Christensen, 1992a; 1992b). The candidate believed that the limitation at component level would not impede the development of their ambidexterity model. Moreover, the candidate suggests that their ambidexterity model could provide greater insight into why component level innovation may not achieve an S-curve trajectory.

The candidate believed that a foundation was established in TRAJ theory and concluded the survey by searching for deeper insights into the reasons why a TP/CP shift occurred in Dosi's (1982) model. The candidate again drew on Feigenbaum (1956) because he is regarded in this dissertation as a pioneer in the entrenchment of the customer-pull model in Western manufacturing theory, which was dominated historically by MP. The candidate located two more papers, which provided academic elaboration on the reasons for a TP/CP shift. Dosi and Grazzi (2010) provided a concise overview of TP/CP from an interdisciplinary perspective, which harmonised technological trajectories, production inputs, process development and organisational learning. Paap and Katz (2004) provided a dynamic model of innovation, which explained the interaction between an innovation's drivers, its leverage to influence adoption and its productivity. A key feature of Paap and Katz's (2004) model was its ability to incorporate the perspectives of internal and external customers. Here, the candidate can relate innovation theory to the economic theory of supply-demand in this dissertation.

The candidate found no reported reference to technological trajectories within the literature for Toyota innovation theory. However, the candidate expects to show that Kondou's (2003) theory of *kakushin* as representing eras and the recent appearance of the concept of cycles of industry in Toyota's public promotion (Toyota Motor Corporation, Public Affairs Division, 2008), can be regarded as indirect references.

**Dominant design (DOM).**

The survey for TRAJ revealed that the emergence of a dominant design is reported in the literature as a precipitative event in the evolution of an industry. The candidate believed that the concept of a dominant design could be used in their analytical framework as a key element. Here, the candidate expects to show that dominant designs can be used to explain the stimulus for the organisation of manufacturing systems to LM.

The candidate's survey concentrated on understanding dominant designs profoundly. Anderson and Tushman (1990) explained explicitly how dominant designs are formed and their relationship to technological trajectories. The candidate realised that Anderson and Tushman (1990) provided a vital supplement to Clark's (1985) framework, by explaining the timing of dominant designs and their impact on the social processes within organisational evolution. Anderson and Tushman (1990) introduced a behavioural element, which is related to strategic decision making and the direction of organisational learning. A paper by Suarez and Utterback (1995) was regarded highly by the candidate because of its research on dominant designs within the automotive industry. Here, the theory of the dominant design was deepened to explain its effect on industry structure and strategic organisational decision making. A key outcome from Suarez and Utterback (1995) was that dominant designs can have far reaching consequences, which impacted the entire structure of an industry beyond its original founders. Dominant designs stimulated and in turn were influenced by the creation of complementary goods and services, which may be beyond the control of individual producers[7]. The candidate steered the survey in this direction and located four papers, which contained concepts that could be used by this dissertation. An explanation of the influence that complementors had on technological adoption was found in Katz and Shapiro (1986), who provided insight into their strategic manipulation. Suarez (2004) provided a thorough academic overview of how dominant designs shape an industry. Schilling (2003) provided a framework for the practical exploitation of dominant design and complementor theory by producers. Soh (2010) provided significant theory into how a dominant design could be used strategically. Soh explained that an organisation could position itself as an industrial nub, through its entrenchment of an actual or *de facto* industry standard. Soh's research was important to this dissertation because if focussed on the pre-dominant design phase, which can be used to help explain the emergence of MP in the automobile's trajectory.

The candidate found no reported reference to dominant designs within the literature for Toyota innovation theory.

[7] *E.g.* the proliferation of the automobile stimulated standardised and disseminated fuel supply, which in turn stimulated the proliferation of the automobile.

**Technological diffusion (DIFF).**

A key outcome from Dosi's (1982) model and Clark's (1985) framework was that there is a social process of technological diffusion, which is related directly to the process of technological development. The process of technological diffusion explains how and why innovations are adopted and become entrenched. The candidate observed that the literature has reported on several developing phases of technological diffusion research. Rogers is accepted as a pioneer of technological diffusion research through his 1962 text. Here, technological diffusion is explained as different categories of people adopting a technology at different times. Roger's adopter categories and the diffusion of a technology were related academically to an S-curve trajectory, which reflected the cumulative adoption of a technology (Rogers 1962, cited in Schilling 2005). The candidate observed that Roger's theory is accepted throughout the literature as a standard perspective. Bass (1969) then modelled the diffusion of various commodity goods and was also accepted as a pioneer in diffusion research. Here, the S-curve was affirmed as being the dominant trajectory and the role of communication and imitation in diffusion was explained. The psychological and behavioural traits of various adopter categories were expounded in later research, as a means of securing competitive advantages in marketing (Urban and von Hippel, 1988; Foxall, 1994; McDonald and Alpert, 2007).

Whilst the S-curve trajectory dominates the literature, it was reported in Tidd *et al*. (2005) that there are several confirmed trajectories, which have specific applications. A question that required resolution was which trajectory is appropriate for the formation of the analytical framework in this dissertation. The question of appropriateness was resolved through Tidd *et al*. (2005), who explained that S-curves are appropriate for the diffusion of processes, techniques, procedures and consumer products. The candidate believed that this reflected accurately the diffusion of the automobile and the evolution of LM. Moreover, that the S-curve for technological diffusion could be used as an important adjunct to the S-curve for technological development, which resolves the perspectives of consumer and supplier. The candidate noted in Cohen and Levinthal (1990) that the consideration of technological diffusion from the perspectives of consumer and supplier was important.

The candidate's survey revealed that a precipitative event in the entrenchment of an innovation was the formation of a critical mass of adopters, which allowed the "adoption chasm" to be crossed permanently (Moore, 2004, p. 364). According to Moore (2004), the adoption chasm must be crossed in order to develop a mainstream market. Whilst Moore's (2004) adoption chasm was defined from the consumer's perspective, later research by Bernstein and Singh (2008) established that the chasm concept applied equally to the adoption of an innovation within a producer. Here, the candidate reasoned that the emergence of the automobile's dominant design and advent of MP were significant in the automobile crossing the adoption chasm from the consumer's perspective.

Moreover, that the efficiency of LM was significant in LM's proliferation within the automotive industry.

The candidate found no reported reference to diffusion theory within the literature for Toyota innovation theory.

**Strategy (STRAT).**

The candidate believed that strategy theory is required to provide insights into where it is strategic to use LM. The establishment of LM's strategic contextual appropriateness can be used in the formation of an ambidexterity model. The candidate directed the survey to the issue of LM and strategic advantage. The candidate's survey identified two landmark papers, which provided insights into the antecedents of LM holding a strategic position. Hayes and Wheelwright (1979) defined a strategic matrix, which correlated strategic imperatives to effective manufacturing systems. Hayes and Wheelwright (1979) was regarded by the candidate to be important to this dissertation for three reasons. Firstly, it was compiled from the perspective of a product life-cycle, which was regarded by the candidate to mirror the S-curve trajectory for technological development. Secondly, it explained strategy in terms of the dominant competitive modes that manufacturing systems can provide and the key management tasks required. Thirdly, the matrix was compiled before the arrival of LM in the mainstream literature. Whilst there is no reference to LM in Hayes and Wheelwright (1979), the candidate contends that LM can be interpolated in the theory and used to provide a generic relationship between manufacturing paradigm and strategy. Here, LM is appropriate where production flow is a strategic advantage, which is characterised by a mature commodity market. This position was corroborated by Porter (1996), who is accepted as a leader in strategy theory. Porter (1996) made an important contribution to this dissertation, by providing the strategic relationship of LM to technological trajectories. Here, LM is appropriate in the customer-pull era of technological development, which is characterised by operational excellence and exploitation.

The candidate believed that the fundamental strategic context for LM was established and focussed on the issue of strategy and ambidexterity. An earlier paper by Porter (1991) provided the candidate insights into the relationship between strategy and market drivers in a dynamic sense. Here, the candidate determined that a dynamic ambidexterity model must encompass the core concepts of technological trajectories and be founded in terms of exploration and exploitation. Cesaroni *et al.* (2005) provided detailed theory into exploratory and exploitative strategies with specific reference to the automotive industry, which was grounded in the core concepts of dominant designs, technological trajectories and diffusion theory. Three further papers were located by the candidate, which added greater detail to Cesaroni *et al.* (2005). Burgelman (2002) provided detail into how co-evolutionary learning between producers and complementors impacted strategy. Two papers by

Schilling (1998; 2003) elaborated the relationship between dominant designs, complementors and dynamic strategy. The candidate believed that sufficient theory was established for the development of an ambidexterity model, which incorporated specifically LM.

The candidate concluded the survey on STRAT by assessing its presence in the literature for Toyota innovation theory. Here, the assertion that the customer-pull business model is a universally superior strategy was re-confirmed (Womack and Jones, 1991; Liker, 2004; Hines *et al*., 2008; Osono *et al*., 2008). The candidate noted two exceptions, which they regarded as a partial recognition of the need for dynamic strategy. Whilst endorsing customer-pull, Osono *et al*. (2008) reported on the benefits that Toyota could enjoy from the implementation of strategic contradictions, as a means of inciting ambidexterity in innovation. Similarly, whilst endorsing customer-pull, Imai (1986) reported on the benefit to LM that can occur from strategically timed radical innovation.

**Ambidexterity (AMB).**

Whilst the contextual conditions under which LM was appropriate had been established, a requirement of the dissertation must be a thorough survey of ambidexterity theory. Ambidexterity research concerns the management of exploration and exploitation. Raisch and Birkinshaw (2008) researched the development of ambidexterity theory and its core research themes. They concluded that ambidexterity was an emerging theory, which required deeper interdisciplinary cooperation. Moreover, whilst research into exploration and exploitation has contributed greatly to the understanding of how the productivity and innovator's dilemmas manifest, the theory of how to achieve ambidexterity is less developed. The candidate determined that their survey should focus initially on the issue of the antecedents to exploration and exploitation. Then, on the issue of the how exploration and exploitation can be managed.

The candidate's survey found that the literature for the antecedents to exploration and exploitation reported primarily on patterns in organisational learning, process development and organisational capabilities. Key papers included March (1991), Benner and Tushman (2002) and Zollo and Winter (2002). March (1991) was influential in the literature because of his exposition of the role of organisation learning in innovation. Here, the exploitation of old certainties dampens the exploration of new possibilities. Benner and Tushman (2002) were influential in the literature because of their research into the relationship between process development and exploitation, which found that process development *per se* is exploitative. Zollo and Winter (2002) investigated the evolution of organisational capabilities and found that routinised capabilities that are founded in accumulated experience and codified knowledge propel exploitation. The candidate regarded these papers as foundational for establishing the mechanics[8] behind the productivity and innovator's dilemmas.

[8] The mechanics behind the productivity and innovator's dilemma will be expounded in Chapter 7 of this dissertation.

The candidate's survey found that research into the management of exploration and exploitation was concerned primarily with the application of the theory of the antecedents to exploration and exploitation towards the formation of practical ambidexterity models. The candidate noted the existence of various ambidexterity models and then searched the literature for a resolution to the issue of the appropriateness of existing ambidexterity models in this dissertation. Gupta *et al*. (2006) researched the issue of multiple ambidexterity models and concluded that they can be characterised by two types. The first type is the duality approach, which argues for the simultaneous pursuit of exploration and exploitation. The second type is the punctuated equilibrium approach, which argues for the switching between exploration and exploitation according to time-based strategy. Gupta *et al*. (2006) made two conclusions which were regarded by the candidate to be significant to this dissertation. Firstly, both approaches are effective, depending on context in which they are applied. Secondly, lower order processes can be unburdened from balancing exploration and exploitation by a high order system. Here, the candidate contends that Gupta *et al's* (2006) conclusions reflect technological trajectories because S-curves are a high order system, which is dynamic according to context. A corollary from the candidate's contention is that the balance of exploration and exploitation in ambidexterity varies according to the transition from pure technology-pushed exploration to pure customer-pulled exploitation as a paradigm develops. Hence, a transition point exists in the migration between technology-push to customer-pull, which represents maximum ambidexterity in both exploration and exploitation. The candidate's contention can be summarised as a punctuated equilibrium model to ambidexterity that encompasses variable time-based duality, which is characterised by a shifting balance between exploration and exploitation and an ambidexterity limit. The candidate found support for their contention of an ambidexterity limit in He and Wong (2004). He and Wong (2004) observed that the duality approach was centred generally on academic derivation and lacked empirical testing. He and Wong (2004) produced a rare and influential paper in the literature, by their empirical testing of the duality hypothesis in 206 manufacturing firms. Here, He and Wong (2004) suggest that there may be a limit to the duality approach, because of the pressure of maintaining antagonistic objectives when pushed to extremes.

The candidate notes that their contention of LM ambidexterity challenges the Toyota model of ambidexterity within the literature for Toyota innovation theory. The research of Osono *et al*. (2008) and Takeuchi *et al*. (2008) reports that Toyota uses in part the duality approach to ambidexterity. Here, it is argued that ambidexterity is provoked by the setting of contradictory objectives by management. *E.g.* Observe frugality but spend heavily in key areas. The candidate noted a significant outcome from the research of Osono *et al*. (2008) and Takeuchi *et al*. (2008). Adler *et al*. (2009) researched the state-in-the-art in the resolution of the productivity and innovator's dilemmas and suggested that Toyota may be capable of bypassing them. Adler *et al*. (2009) combined the duality approach to ambidexterity reported by Osono *et al*. (2008) and Takeuchi *et al*. (2008) with Toyota's emphasis on *kaizen*. Adler *et al*. (2009) argued that *kaizen* combined with a duality approach to ambidexterity may be sustainable. The candidate observed that Adler *et als*' argument was founded on three concepts. Firstly, *kaizen* provokes innovation in that disruptions to the *status quo* require an immediate response. Secondly, *kaizen* implies continuous improvement, which may result in the ongoing enhancement of duality based ambidexterity capability. Thirdly, whilst *kaizen* and *kakushin* achieve opposing outcomes, their innovation processes are the same. Here, the candidate expects to show that Toyota ambidexterity theory is unsuccessful fundamentally in enabling *kakushin* and is successful partially in enabling *kaikaku*. The candidate's assertion is based on two key points. Firstly, *kaizen* and *kaikaku* act within a technological paradigm and *kakushin* acts outside of extant technological paradigms. Secondly, the innovation process for *kaizen* is different fundamentally to *kakushin*. The candidate elaborates these points in that *kaizen* and *kaikaku* represent degrees of innovation within a duality approach to ambidexterity whereas *kakushin* represents punctuated equilibrium.

The candidate concluded their survey of AMB by locating theoretical detail, which could be used to integrate LM into this dissertation's ambidexterity model. The candidate expects to show in later chapters of this dissertation that a key feature of LM and the domination of *kaizen* within Toyota innovation theory is the formation of highly integrated supply chains. The candidate located three papers, which provided insights into how supply chains form and could be managed from the perspective of ambidexterity. Lavie and Rosenkopf (2006) provided significant theory into how supply chains develop exploitative capabilities. Teece (2007) contributed significant theory into how dynamic capabilities could be formed within supply chains. Insights into the general management of exploitation and exploration from the perspective of process design within supply chains was provided by Benner and Tushman (2003).

***Economic perspective of technological development.***

Dosi's (1982) model was underpinned by economic drivers, which represented the formation of a market. A requirement of the dissertation must therefore be a profound understanding of the fundamental dynamics between producers and consumers.

**Utility and value (UTIL/VAL).**

According to Hines *et al*. (2004) a lean enterprise designs products that satisfy customer needs, because these products are valued by them. Yet, the research rationale explained that an equally valid approach was to create needs in customers through technology-push. Here, there were two issues that required resolution in this dissertation. Firstly, how value is perceived by customers from the opposing perspectives of technology-push and customer-pull. Secondly, how the concept of value can be reconciled between the opposing perspectives of technology-push and customer-pull.

The candidate noted that the concept of value in economic literature is rooted in utility, which is regarded as an indirect measure of consumer behaviour in monetary terms. Economic theory assumes that consumers spend their money in a way that provides them satisfaction, or utility. The total utility derived from the purchase of a good represents the maximum amount of money a consumer is willing to exchange for it (Baumol and Blinder, 2005).

Here, the candidate contends that total utility represents a purchase decision threshold, which varies between and within consumers based on their concepts of the benefit derived from purchasing a good. The variation in consumer concepts of value allows this dissertation to relate value to adopter categories and technological trajectories. Grebel researched the issue of how economic utility behaves in technology-push and customer-pull markets. Grebel demonstrated that in the mature customer-pull era of a technological trajectory the economic concept of utility behaved normally, according to entrenched market selection mechanisms. However, in the trajectory's technology-push era, these selection mechanisms were absent. Here, the technology was not beholden to the economic laws of utility because of its novelty (Grebel, 2009). The candidate reasoned that consumers in the early part of a product's development and diffusion must have different perceptions of value than mainstream consumers in a commodity market. The candidate then concentrated their survey to locate theory that could be used to explain the differences in value perception and how they could be reconciled in an ambidexterity model. Franke *et al*. explained that the purchase of goods may be based on their ability to serve either a hedonic or utilitarian purpose. A hedonic good, is valued for its novelty and the positive emotional stimulus it provides. A utilitarian good, is valued for its pragmatic application (Franke *et al*., 2009). Witt (2010) elaborated that a hedonic good may be valued for its symbolic meaning and the signal it transmits upon its purchase. Here, the candidate believes that foundational theory was established for the formation of a continuum of value perception, which could be used to underscore technological trajectories.

Having established a relationship between value and technological trajectories, the candidate believed that this dissertation required greater depth in the theory of consumer behaviour and how it relates to LM. Based on Grebel (2009), the candidate regarded the contemporary automobile as exhibiting behaviour according to the normal[9] laws of economic utility. The candidate reasoned that in being the contemporary market leader in sales, Toyota excels in the provision of utilitarian goods, which are valued for the satisfaction they provide in meeting entrenched customer needs. The candidate believes that this point is made salient in that Toyota is a relatively late entrant to the automotive industry. The candidate then directed their survey to the location of theory that could be used to explain the dominance of Toyota from the perspective of the consumer. Kamins *et al*.

[9] The candidate excludes the 2008 global financial crisis from this point on the basis that it is not specific to the automotive industry.

showed that brand perception influences purchasing behaviour. Whilst product innovators held typically the advantage of positive perceptions from their pioneering status, of greater bearing on positive brand perception was the advantage of market leadership. Here, brand perception is mutable and can be developed positively to enhance market position (Kamins *et al*., 2003). Del Rio *et al*. explained that brand image is a multi-attribute construct. Positive brand image depends on the strength of association between specific attributes and the way consumers perceive them. Del Rio *et al.* researched commodity markets and found that the confidence a product inspired, through its performance, quality, value for money and sensitivity to customer needs is a powerful attribute to exploit (del Rio *et al*., 2001). Bowman and Gatignon (1996) researched the exploitation of the attribute of product confidence by late market entrants and reported that whilst it is their principal strategy, it requires more effort than early entrants. The intensified effort required by late market entrants is elaborated by Anderson and Salisbury (2003) and Homburg *et al*. (2006). Anderson and Salisbury researched the formation of consumer expectations and found that a perceived decline in brand status had a greater impact on consumer perceptions than activity directed to brand enhancement[10]. Here, it was important for late entrants to maintain consistency because set-backs in brand image may not be redeemable (Anderson and Salisbury, 2003). This point is reinforced by Homburg *et al*. through their research into the formation of customer satisfaction. Homburg *et al*. found that customer satisfaction was founded in positive early experiences and cumulative consistency (Homburg *et al*., 2006). The candidate contends that Toyota's rise to market leadership is reflected in the theory for utility and value. Toyota's primary strategy was customer-pull, product confidence and consistency in the provision of a utilitarian good.

The candidate concluded their survey on UTIL/VAL by strengthening their assertion that LM producers are vulnerable to disruption, from the perspective of utility and value. Homburg *et al.* (2005) researched the relationship between willingness-to-pay and customer satisfaction. Here, it was demonstrated that an inverse S-curve function exists, which is characterised by two implications. Firstly, the pursuit of customer satisfaction from customer-pull is a powerful purchasing influence on consumers with low satisfaction experience. Secondly, the benefit from providing customer satisfaction to the mainstream market tends to diminishing returns. The candidate reasoned that customer satisfaction can be regarded as a mandatory requirement in the contemporary automotive market. Based on Homburg *et al*. (2005), it could be argued that in this context the pursuit of customer satisfaction as a competitive advantage results in increasing effort for diminishing returns.

The candidate found that within the literature for Toyota innovation theory there were two direct references to UTIL/VAL theory. Hines *et al*. (2004) and Hines *et al*. (2008) defined explicitly how value

[10] Toyota suffered massive product recalls from various quality issues in 2010. Whilst this was a historical aberration and the antithesis of Toyota's values, it could be argued that decades of positive perception cultivation was undone in one blow.

is created in LM, which the candidate observed accords with the economic and behavioural theory presented in this dissertation.

**Producer/consumer dynamics – supply and demand (SUPP/DEM).**

The candidate believed that the economic interaction between producers and consumers required fortification within this dissertation. Whilst Dosi's (1982) paper provided a model, a subsequent paper by Dosi (1988) provided the micro-economic theory behind technological trajectories. A text by Baumol and Blinder (2005) was regarded by the candidate to be a sound general resource for economic theory. Here, the candidate noted a key concept, which could be used to elaborate value, utility and purchase decision dynamics from both the producer and consumer perspectives. Opportunity cost, or the next best alternative that must be forgone[11] in an economic decision may be used to provide insight into competitive options and priorities. Here, the candidate believes that opportunity cost provides a greater sense of the true value of an investment and could be used as a metric in this dissertations analytical framework.

The candidate's survey found no reportable references within the literature for Toyota innovation theory to the economic theory of supply and demand.

***Behavioural perspective of technological development.***

Whilst the organisation of manufacturing systems and markets may be explained as patterns found in innovation and economic theories, they are enacted through individuals and groups. A requirement of this dissertation must be a profound understanding of how human behaviour maintains cohesion in these patterns.

**Decision making (DEC).**

The candidate reasoned that because technological development and diffusion follow generally ordered patterns, then so too must the underlying decisions of producers and consumers. DIFF, UTIL/VAL and SUPP/DEM explained the antecedents to behaviour from the consumer's perspective. The candidate then directed their survey to the issue of antecedents to behaviour from the producer's perspective. Here, the candidate searched for literature that provided foundational decision making theory.

Brunswik's lens model of judgement is accepted as a foundational perspective for the explanation of how judgement varies between individuals. Brunswik explained that judgement was biased by the cues selected and the weighting attributed to them. Brunswik argued that the prevailing nature of decision making is compromised by flawed perceptions, which result in quasi-rational decisions. Quasi-rational decisions can be regarded as a compromise between rationality and intuition

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[11] *E.g.* investing in shares means that one may be required to forgo investment in real estate.

(Brunswik, 1952). Cooksey developed Brunswik’s (1952) lens model into social judgement theory, whereby judgement varied between and within individuals according to variation in their surrounding ecology. Here, pure rational decision making is an exception (Cooksey, 1996). Whilst this may discount rational decision making, the candidate found in Jungermann (1983) that although judgements and perceptions may be flawed, they are grounded inevitably in general rationality. The candidate located two papers, which explained how decisions may become flawed and biased. Kahneman and Tversky (1984) explained how values and the way a situation was framed influenced the perception of risk and the choices made. Vroom and Jago (1974) explained that there are social processes that may influence decisions, whereby individuals and groups colour decisions. Elaboration was provided in Parkin’s (1996) text, which the candidate regarded to be a sound general resource for decision making theory. The candidate concluded their survey by locating two papers, which explained the dynamics of group decision making. Porac *et al*. (1989) provided landmark theory into how experienced and successful teams may develop a shared mental model, which continued to propel them forward. Thomas-Hunt *et al*. (2003) provided valuable insights into how established groups interact with new or non-conforming individuals. The candidate is confident that despite the modest citations a solid foundation has been established, which can be used to explain decision making in LM and guide advanced literature surveys in this dissertation.

The candidate’s survey found no reportable references within the literature for Toyota innovation theory to decision making theory.

**Enterprise structure (STRUCT)**.

The candidate noted throughout their survey the influence that enterprise structure had on manufacturing systems and innovation focus. According to Ohno (1988), a fundamental enabler of LM was Toyota’s restructure from Ford’s (1926) vertically centred autocracy to a decentralised *kaizen* democracy. Whilst the literature on Toyota innovation theory described the elements of LM structure and their capacity to facilitate customer-pull and *kaizen*, the candidate believed that deeper insights were required from the perspective of behavioural theory. Mintzberg described an enterprise as organised human activity, where the enterprise’s structure reflected the way its labour was divided into tasks and how their coordination was achieved. Mintzberg argued that there are only a few basic structures upon which enterprises are based, which follow a predetermined and evolutionary order (Mintzberg, 1983). LM was regarded by the candidate as a complex system designed for exploitation, which represented the most evolved highly of the structures defined by Mintzberg. Here, the candidate reasoned that if the relationship between enterprise structure and exploitation could be established conclusively, then it could be used as the antithesis to an exploratory structure in an ambidexterity model.

Ohno (1988) emphasised the role of LM structure and its contrast to MP, in the ability of LM's structure to facilitate *kaizen*. The paper by Kok and Biemans found that structures *per se* can induce attitudes and behaviours in exploitative enterprises. Here, a *kaizen* culture can be induced in non-exploitative organisations through reconfiguration to an exploitative structure (Kok and Biemans, 2009). Anand *et al*. (2009) showed similarly, in that the total integration of infrastructure and systems oriented towards continuous improvement contributed significantly to the development of *kaizen* capability. Kok and Biemans (2009) and Anand *et al*. (2009) reinforced a landmark paper by Benner and Tushman who established that process organisation *per se*, through structures or systems, was consistent with an exploitative orientation towards continuous improvement (Benner and Tushman, 2002). The candidate's survey can cite several papers which provided powerful reasons why an exploitative enterprise structure fosters *kaizen*. The candidate will elaborate in detail the structure of LM in Chapters 5 and 6 of this dissertation, however here presents some key structural features. The candidate observed that Ohno's (1988) restructure of Toyota from a basic MP configuration to a full LM manufacturing configuration disseminated the decision locus and placed the focus of innovation on process improvement. Fredrickson (1986) provided a framework, which explained the relationship of decision making to enterprise structure. Here, it was possible for the candidate to compare Ford's (1926) MP to Ohno's (1988) LM. Decision making in Ford's enterprise structure was concentrated at the top and predisposed to strategic decisions. Conversely, in the integrated LM structure where workers are empowered, decision making gravitates towards becoming incremental, because of the need for political bargaining and consensus. Whilst Ford (1926) dictated activity through narrow and specified job roles, Ohno (1988) relied on teamwork and participation in innovation from all employees. Teamwork and participation was required by Ohno in order to maintain the synchronicity needed to affect customer-pulled flow and perfect efficiency. Ford's (1926) structure divided activities by function and coordinated them centrally, whilst Ohno's (1988) structure was founded on multi-skilling and autonomous teamwork. Here, the candidate again used Fredrickson's (1986) framework to note that in LM, strategic decisions are likely to be unrecognised or ignored in favour of parochial interests. The candidate's survey located three key papers, which elaborated this point. Siggelkow and Rivkin established that the dissemination of decision making throughout the lower echelons was a potent inducer of innovation at the local level. This was because the lower echelons were empowered to screen innovation options and tended to favour those options which served parochial interests (Siggelkow and Rivkin, 2006). Siggelkow and Rivkin (2006) accorded with Levinthal and March (1993, p. 110) who argued that synchronised activity results in learning that has spatial and temporal bias akin to "myopia", which is oriented towards the immediacy of events. Rivkin provided insights into how LM evolved as a system. The candidate noted that according to Rivkin, LM constituted a complex system, which is reliant on knit tightly interdependencies. Here, a small error can magnify and have gross implications. The need to prevent errors fosters a focus on processes and their control, which gravitates the system towards a steady-state. Adjustments to the system become incremental, because these are less disruptive and can be implemented relatively quickly (Rivkin, 2000). The candidate believed that a foundation was established, which explained the relationship between enterprise structure and exploitation.

The candidate can cite several texts within the literature for Toyota innovation theory, which related enterprise structure to exploration and exploitation. The most important literature related to this dissertation was Cusumano (1988), Ohno (1988), Krafcik (1988) and Womack *et al*. (1991). Cusumano (1988) provided insights into how LM structure facilitates *kaizen* and how MP structure does not. Here, the candidate believes that MP's resistance to *kaizen* can be explored further as a means of developing a model of exploratory enterprise structures. Similarly, Ohno's (1988) exposition of the differences between LM and MP structures can be explored. Whilst lacking detail, the candidate regarded Krafcik (1988) and Womack *et al.* (1991) to be fundamental to this dissertation. Krafcik (1988) and Womack *et al*. (1991) considered LM within the context of MP and their distant antecedent of craftsmanship manufacturing, which dominated automobile manufacturing before MP. Here, the candidate expects to show that this is a critical relationship, which can be explored deeply to present a new perspective on LM and exploratory enterprise structures.

Two other texts were located by the candidate, which related LM structure to exploitation. Harrison (2000) related the social processes required for *kaizen* to enterprise structure. Monden (1994) explained in detail the layout of LM manufacturing systems and their relationship to *kaizen*.

**Personality types (PERS).**

The candidate noted that in the literature for Toyota innovation theory the importance of an appropriate mindset was emphasised (*e.g.* Liker, 2004; Liker and Hoseus, 2008). Moreover, Osono *et al*. (2008) explained that Toyota employees are mentored and coached continually and that rigorous selection mechanisms for recruitment and promotion exist based on a compatible mindset. Here, the candidate directed their survey to the location of theory that could be used to explain the personality type(s) suitable for LM.

Kirton (1976) described comprehensively the contrasting personality traits of innovators and adapters on a continuum of cognitive styles. Kirton (1976) allowed the candidate to relate personality traits to exploration and exploitation. Here, innovators have a propensity for exploration and adapters have a propensity for exploitation. An important assertion by the candidate in the research rationale was that LM has contextual appropriateness, in which a specific proactivity focus is a key element. Using Kirton (1976), it can be said that LM has a proactivity focus configured to exploitation. Here, the candidate conceives the concept of a proactivity dilemma, which is congruent with the productivity and innovator's dilemmas. The proactivity dilemma asserts that as proactivity grows in exploitation, exploration is perceived increasingly as non-proactive. Exploitation can be regarded as proactive behaviour within a LM context. However, according to Kirton (1976), proactive exploitation is antagonistic to exploration from the perspective of personality types. A corollary of the proactivity dilemma is that as an enterprise excels in exploitation, it becomes increasingly populated with and dominated by personality types that have a propensity for exploitation. The proactivity dilemma is aligned with the productivity and innovator's dilemmas in that successful exploitation has consequences if an exploratory footing is required. Proactivity in exploitation may be regarded as undesirable and ineffective in an exploratory context. Hence, exploration and exploitation can both be considered to be proactive or non-proactive behaviours, depending on the innovation context they are applied in. The candidate then directed their survey towards research into proactive behavioural traits. Fresh research was detected in a paper by Parker and Collins, which can be argued to support the candidate's assertion of the productivity dilemma. Parker and Collins (2010) found the existence of multiple proactive behavioural categories and that individuals may have a propensity in one domain of proactivity and not others. The candidate noted that the proactivity categorisation in Parker and Collins (2010) aligned broadly with Kirton (1976) and could be applied to LM and the development of this dissertations' ambidexterity model.

**Discussion of key findings (Part B).**

A summary of relevant literature and the candidate's rankings are shown in Table 8, which shows rankings from the interdisciplinary perspective as **R (I)** and the Toyota innovation theory perspective as **R (T)**. Key findings are summarised by the candidate as follows. There is profound theory from the interdisciplinary perspective that can be used to explain academically the antecedents of Toyota's current position and reconcile its innovation mechanisms through an ambidexterity model. The relationship of Toyota innovation theory to fundamental interdisciplinary theory is absent or underdeveloped relatively. The candidate regards this as a reflection of the historical dominance of *kaizen* and the newness of ambidexterity research in the literature for Toyota innovation theory.

*Table 8: Summary of the Candidate's literature survey on the fundamental relationship between Toyota and interdisciplinary theories.*

| CRITERIA | LITERATURE (I) | DESCRIPTION *(interdisciplinary literature)* | R (I) | LITERATURE (T) *(Part A literature surveyed according to Part B selection criteria)* | R (T) |
|---|---|---|---|---|---|
| **AMB** | Adler *et al*. (2009). | Ambidexterity synopsis. | 4 | Adler *et al*. (2009). | 2 |
| | Benner and Tushman (2002). | Exploitation antecedents. | 4 | Osono *et al*. (2008). | 2 |
| | Benner and Tushman (2003). | Ambidexterity management. | 4 | Takeuchi *et al*. (2008). | 2 |
| | Gupta *et al*. (2006). | Ambidexterity dynamics. | 4 | | |
| | He and Wong (2004). | Ambidexterity limits. | 4 | | |
| | Lavie and Rosenkopf (2006). | Ambidexterity antecedents. | 3 | | |
| | March (1991). | Explore/exploit antecedents | 4 | | |
| | Raisch and Birkinshaw (2008). | Ambidexterity antecedents. | 4 | | |
| | Teece (2007). | Ambidexterity antecedents. | 3 | | |
| | Zollo and Winter (2002). | Exploitation antecedents. | 4 | | |
| **DEC** | Brunswik (1952). | Judgement theory. | 4 | | |
| | Cooksey (1996). | Judgement theory. | 4 | | |
| | Jungermann (1983). | Judgement theory. | 4 | | |
| | Kahneman and Tversky (1984). | Risk perception. | 4 | | |
| | Parkin (1996). | Decision theory overview. | 4 | | |
| | Porac *et al*. (1989). | Mental model antecedents. | 4 | | |
| | Thomas-Hunt *et al*. (2003). | Group dynamics. | 4 | | |
| | Vroom and Jago (1974). | Decision and social processes. | 4 | | |
| **DIFF** | Bass (1969). | Diffusion theory. | 3 | | |
| | Bernstein and Singh (2008). | Supplier critical mass. | 3 | | |
| | Cohen and Levinthal (1990). | Absorptive capacity. | 4 | | |
| | Foxall (1994). | Adopter personalities. | 3 | | |
| | McDonald and Alpert (2007). | Market exploitation. | 4 | | |
| | Moore (2004). | Consumer critical mass. | 4 | | |
| | Schilling (2005). | Adopter categories. | 4 | | |
| | Tidd *et al*. (2005). | S-curve limitations/application. | 4 | | |
| | Urban and von Hippel (1988). | Lead-user exploitation. | 3 | | |
| **DOM** | Anderson and Tushman (1990) | Dominant design formation. | 4 | | |
| | Clark (1985). | Design hierarchy. | 4 | | |
| | Katz and Shapiro (1986). | Complementor effects | 4 | | |
| | Schilling (2003). | Complementor strategy | 4 | | |
| | Soh (2010). | Network strategy. | 3 | | |
| | Suarez and Utterback (1995). | Strategy and industry structure. | 4 | | |
| | Suarez (2004). | Strategy overview. | 4 | | |
| **PERS** | Kirton (1976). | Explorers vs. exploiters. | 4 | Liker (2004). | 2 |
| | Parker and Collins (2010). | Proactivity antecedents. | 4 | Liker and Hoseus (2008). | 2 |
| **STRAT** | Burgelman (2002). | Strategy and learning. | 4 | Imai (1986). | 2 |
| | Cesaroni *et al*. (2005). | Ambidexterity strategy. | 4 | Osono *et al*. (2008). | 2 |
| | Hayes and Wheelwright (1979). | Strategy and lifecycles. | 4 | | |
| | Porter (1991). | Dynamic strategy. | 3 | | |
| | Porter (1996). | Strategy and exploitation. | 4 | | |
| | Schilling (1998). | STRAT/DOM/ complementors. | 4 | | |
| | Schilling (2003). | STRAT/DOM/ complementors. | 3 | | |
| **STRUCT** | Anand *et al*. (2009). | Exploitative infrastructure. | 3 | Cusumano (1988). | 3 |
| | Benner and Tushman (2002). | Processes as exploitation. | 4 | Harrison (2000). | 2 |
| | Fredrickson (1986). | Structure and decision type. | 4 | Krafcik (1988). | 2 |
| | Kok and Biemans (2009). | Structure and change. | 3 | Monden (1994). | 2 |
| | Levinthal and March (1993). | Structure and learning. | 4 | Ohno (1988). | 3 |
| | Mintzberg (1983). | Dynamic structural change. | 4 | Womack *et al*. (1991). | 1 |
| | Rivkin (2000). | Interdependency implications. | 4 | | |
| | Siggelkow and Rivkin (2006). | Structure and decision locus. | 4 | | |

| | | | | | |
|---|---|---|---|---|---|
| **SUPP/DEM** | Baumol and Blinder (2005). | Economic overview. | **4** | | |
| | Dosi (1982). | Techo-economic evolution. | **4** | | |
| | Dosi (1988). | Producer/consumer interaction. | **4** | | |
| **TP/CP** | Brem and Voigt (2009). | Theory synopsis. | **4** | Hines *et al*. (2004). | **2** |
| | Dosi (1982). | Reconciliation. | **4** | Hines *et al*. (2008). | **2** |
| | Hopp and Spearman (2004). | Production perspective. | **4** | Imai (1986). | **3** |
| | Ortt *et al*. (2008). | Theory synopsis. | **4** | Monden (1994). | **2** |
| | Sandberg (2007). | Needs evolution/forecasting. | **3** | Ohno (1988). | **1** |
| | Teece (2008). | Strategy synopsis. | **3** | Stewart and Raman (2007). | **2** |
| | Wonglimpiyarat (2004). | Theory synopsis. | **4** | | |
| **TRAJ** | Abernathy and Utterback (1978) | Process evolution. | **4** | Kondou (2003). | 2 |
| | Christensen (1992a). | S-curve limitations/application. | **3** | Toyota Motor Corp. (2008). | 1 |
| | Christensen (1992b). | S-curve limitations/application. | **4** | | |
| | Clark (1985). | Design hierarchy. | **4** | | |
| | Dosi (1982). | Paradigms and trajectories, | **4** | | |
| | Dosi and Grazzi (2010). | Multidisciplinary synopsis. | **4** | | |
| | Feigenbaum (1956). | Lean manufacturing origins. | **3** | | |
| | Henderson and Clark (1990). | Architectural innovation. | **4** | | |
| | Paap and Katz (2004). | S-curve drivers. | **4** | | |
| | Steele (1997). | Technological eras. | **4** | | |
| | Utterback and Abernathy (1975) | Process evolution. | **4** | | |
| **UTIL/VAL** | Andersen and Salisbury (2003). | Customer perception dynamics | **3** | Hines *et al*. (2004). | **4** |
| | Bowman and Gatignon (1996). | Customer perception dynamics | **4** | Hines *et al*. (2008). | **4** |
| | del Rio *et al*. (2001). | Brand and perceptions. | **3** | | |
| | Franke *et al*. (2009). | Hedonic and utilitarian goods. | **4** | | |
| | Grebel (2009). | Utility and trajectories. | **4** | | |
| | Hines *et al*. (2004). | Lean utility and value theory. | **4** | | |
| | Homburg *et al*. (2005). | Utility and satisfaction. | **4** | | |
| | Homburg *et al*. (2006). | Utility and diffusion. | **4** | | |
| | Kamins *et al*. (2003). | Leadership and perceptions. | **3** | | |
| | Witt (2010). | Symbolic value. | **4** | | |

## 2.5 CONCLUSIONS FROM THE LITERATURE SURVEY

Gaps in the literature within the context of the research rationale from the perspective of Toyota innovation theory were quantified in Table 6 and discussed in Part A of this chapter. Similarly, gaps from the perspective of interdisciplinary theory were quantified in Table 8 and discussed in Part B. An executive summary of the gaps in the literature, the candidate's criticism of the literature and how the candidate will address these issues in this dissertation is summarised in Table 9 below.

The candidate believes that the literature survey justifies the research rationale and provides grounds for prosecuting the dissertation objectives.

*Table 9: Executive summary of the Literature Survey.*

| GAPS IN THE LITERATURE | CANDIDATE'S CRITICISM OF THE LITERATURE | HOW THE CANDIDATE WILL ADDRESS THESE ISSUES |
|---|---|---|
| *Toyota Innovation Theory* | | |
| *Kakushin* is absent effectively.<br>*Kaikaku* is reconciled partially. | The absence of *kakushin* and partial reconciliation of *kaikaku* reflect the discounting of their role in ongoing sustainability. | The candidate expects to show that the literature reflects fundamentally Toyota's historical contextual conditions. |
| Fundamental interdisciplinary theory is weak or absent. | The literature focuses pre-dominantly on manufacturing. | The candidate expects to show that the reconciliation of *kakushin*, *kaikaku* and *kaizen* requires a pre-dominant focus on innovation theory. |
| *Interdisciplinary Theory* | | |
| *Kakushin* and *kaikaku* are reconciled partially. | There is vagueness about what *kakushin* and *kaikaku* are. | The candidate expects to show that *kakushin* and *kaikaku* are different processes that can be represented on a continuum. |
| Universal model of ambidexterity is not reported. | There are competing models of ambidexterity. | The candidate expects to show that the competing models of ambidexterity can be represented on a continuum. |
| | Methods and tools for ambidexterity require significant development. | The candidate will survey in depth this issue in Chapter 7 of this dissertation. The candidate expects to use a continuum to define the methods and tools for ambidexterity according to appropriate contextual conditions. |
| Mono-disciplinary approach is used pre-dominantly. | A mono-disciplinary approach results in competing models of ambidexterity and impedes the development of a universal model of ambidexterity. | The candidate expects to show that an interdisciplinary approach is required in order to develop a universal model of ambidexterity. |

**2.6 SUMMARY.**

This chapter established the state-of-the-art in Toyota innovation theory through a literature survey by the candidate. A survey was instituted to determine the degree of academic reconciliation between *kakushin* and *kaizen* in the literature and to identify theory that could be used to bridge potential gaps. Selection and ranking criteria were developed and applied by the candidate in order to steer the survey. A summary of relevant literature was tabled and cross-referenced against the criteria.

Key findings were discussed and can be summarised as follows. *Kakushin* is new in the literature. Whilst *kakushin* has come to the attention of ambidexterity scholars, its reconciliation within the theory for lean manufacturing is in its infancy. The candidate identified profound theory that can be used to present a new perspective on lean manufacturing, through innovation, behavioural and economic criteria. The fundamental outcome for the strategic argument in Table 3 of this dissertation is that the candidate showed that the research rationale and objectives of this dissertation are justified.

# CHAPTER 3

## A NEW PERSPECTIVE ON LEAN MANUFACTURING

### 3.1 INTRODUCTION.

This chapter outlines the candidate's approach to how lean manufacturing will be evaluated in this dissertation, which forms a foundational part of the strategic argument that is mapped in Table 3 of this dissertation. The candidate will show that a new perspective on lean manufacturing can be presented by utilising the theory the candidate identified in the literature survey of this dissertation. A new perspective can be achieved by the formation of a relationship between lean manufacturing and its predecessors. The chapter concludes with a table of key steps towards the development of an ambidexterity model by the candidate.

### 3.2 ANALYTICAL FRAMEWORK FOR LEAN MANUFACTURING.

The candidate's literature survey established that there is a considerable body of work that explains LM *per se*. It was also established that LM has a direct relationship with MP. The candidate observed that two researchers identified LM as having a distant antecedent before MP called craftsmanship (CR) (Krafcik, 1988; Womack *et al*., 1991). CR was the dominant manufacturing paradigm used during the automobile's origin. The candidate reasoned that CR, MP and LM could be used as a pathway to explain the evolution of LM.

**3 dominant manufacturing paradigms.**

The pathway to LM is central to this dissertation's argument. The candidate contends that the evolution of the automotive industry is characterised by **three dominant manufacturing paradigms**. Moreover, the candidate asserts that the relationship of LM to MP is exposed partially and its relationship to CR is unrecognised fundamentally in the literature for LM. The candidate expects to show that by exploring fully the contributions of CR and MP to LM, the contextual conditions under which the three Toyota innovation mechanisms are effective will be revealed.

**The automobile as a technological paradigm.**

The automobile's displacement of horse-drawn transport is an example of disruptive technology-push. Here, the candidate believes that it is possible to apply interdisciplinary theory and identify the automobile as a technological paradigm. Interdisciplinary theory allows theoretically the reconciliation of the automobile's technology-push origins with its contemporary customer-pull market through a technology trajectory. Precipitative events in a technology trajectory are the formation of a dominant design and an inflexion point. A dominant design is significant to the achievement of a critical mass required to cross an adoption chasm and create a mainstream market.

The inflexion point represents a fundamental shift in innovation focus, which is symbolised by the transition from technology-push to customer-pull.

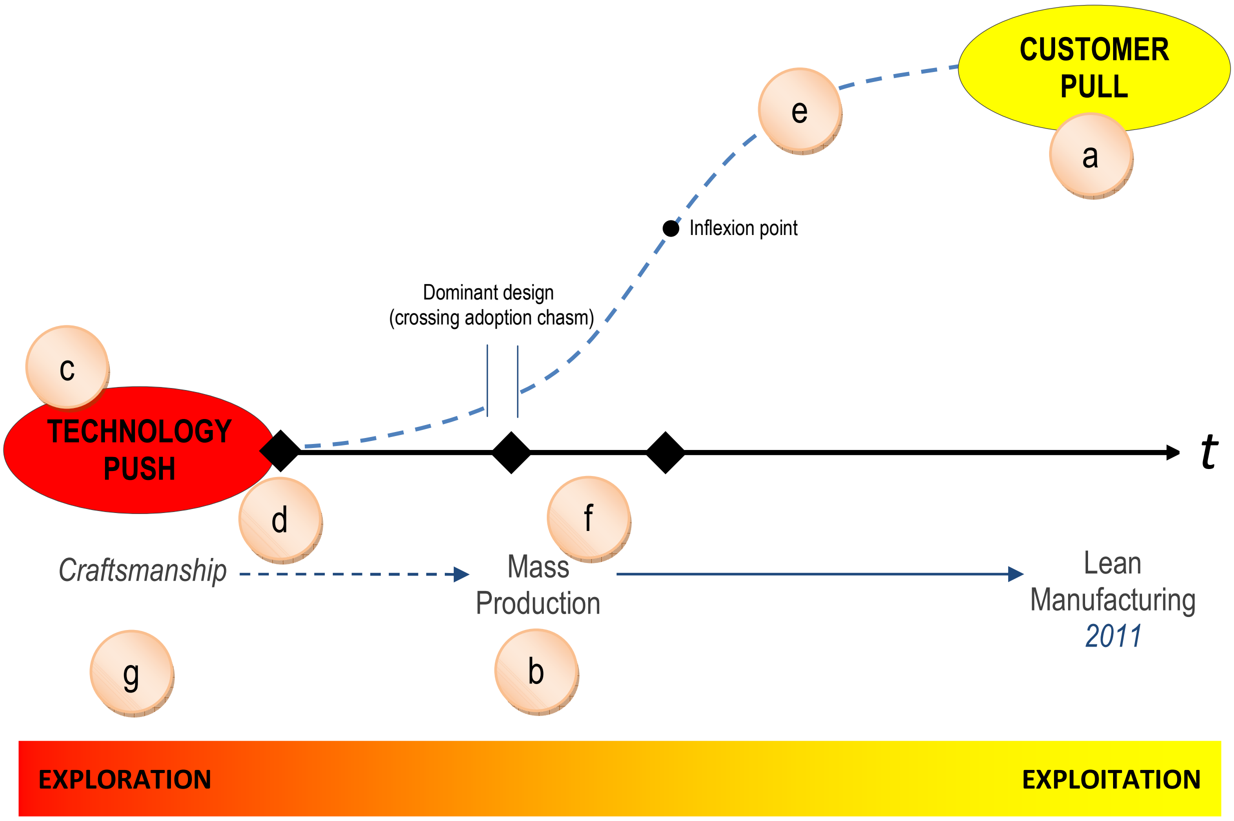
**The automobile as classical technological evolution.**

The candidate expects to show that the automobile has followed a classical technological evolution according to the interdisciplinary theory established in the candidate's literature survey. Here, the automotive industry and LM are framed by time and context in a way that can provide a new insight. The validity of interdisciplinary theory to the automobile paradigm can be confirmed by bringing to light the automobile's technological trajectory. Exposure of the automobile's technological trajectory allows hypotheses to be submitted and tested for the relationship between CR, MP and LM. The assertion that LM is an all encompassing business model could be challenged by arguing that LM is a phase of normal technological evolution. Figure 1 outlines the analytical framework that was developed by the candidate and will be used in this dissertation. The framework will be developed in Chapter 4 of this dissertation, according to the interdisciplinary theory established in the candidate's literature survey and advanced literature survey as required by this dissertation.

# A new perspective on lean manufacturing.

a. The relationship between LM and customer-pull has contemporary application and focus.
b. Yet, it is known that LM evolved directly from MP.
c. Also, that technology-push is an equally valid approach and evolves often into customer-pull.
d. The automobile had a disruptive origin before it became a commodity.
e. Interdisciplinary theory allows a trajectory to be drawn between a disruptive technology-pushed origin and customer-pulled commodity.
f. A trajectory is precipitated by a dominant design and inflexion point.
g. A technology trajectory may show that LM's distant antecedent of CR played an equal role in the automobile's success and is a key element in reconciling *kakushin* with *kaikaku* and *kaizen*.

***Figure 1: A new perspective on lean manufacturing: the Candidate's analytical framework.***




**3.3 KEY STEPS TOWARDS THE DEVELOPMENT OF AN AMBIDEXTERITY MODEL.**

The candidate's analytical framework translates the development of automotive manufacturing systems to the progress of a technological paradigm along a technology trajectory. Here, the functional relationship between the three dominant manufacturing paradigms can be hypothesised. Figure 1 shows that the candidate has represented the automobile's technological trajectory with an explore-exploit continuum. Here, the candidate expects to show that the dominant manufacturing paradigms shown in the analytical framework are consistent with the explore-exploit continuum. The candidate contends that complementary explore-exploit continuums can be revealed for core organisational processes other than manufacturing, which are symbiotic with the dominant manufacturing paradigms. Here, other core organisational processes[12] can be analysed individually in

[12] The analysis of all known core organisational processes is beyond the scope of this dissertation. The candidate will confine this dissertation to the analysis of the core processes used by a typical manufacturing enterprise.

order to determine which of their strategies, methods and tools best support exploration and exploitation. The candidate's contention of a symbiotic relationship between the continuum for the dominant manufacturing paradigms and the continuums for other core organisational processes can be tested with a Systems Analysis Tool, which determines their compatibility as a complete unit. The candidate believes that a symbiotic relationship can be used firstly to establish fully the contextual conditions under which *kakushin*, *kaikaku* and *kaizen* are appropriate and secondly to develop an ambidexterity hypothesis. Here, an enterprise-wide ambidexterity model can be submitted, which has a scope from boardroom strategy to shopfloor tactics. The candidate's final contention is that the enterprise-wide ambidexterity model submitted may resolve effectively the productivity, innovator's and proactivity dilemmas. Table 10 summarises the key steps this dissertation will follow for the development of the candidate's ambidexterity model.

***Table 10: Summary of key steps towards the development of the Candidate's ambidexterity model.***

| STEP | DECRIPTION | DISSERTATION CHAPTER |
|---|---|---|
| 1 | Evaluate LM's evolution within the context of the candidate's analytical framework | Chapter 5 |
| 2 | Hypothesise relationships between CR, MP and LM. | Chapter 6 |
| 3 | Test hypotheses. | Chapter 6 |
| 4 | Establish explore-exploit continuums for core organisational processes. | Chapter 8 |
| 5 | Aggregate explore-exploit continuums into a complete unit and test compatibility. | Chapter 8 |
| 6 | Submit ambidexterity model. | Chapter 8 |

### 3.4 SUMMARY.

This chapter outlined the candidate's approach to how lean manufacturing will be evaluated in this dissertation, which formed a foundational part of the strategic argument that is mapped in Table 3 of this dissertation. The candidate presented a new perspective on lean manufacturing that was supported by the theory the candidate identified in the literature survey of this dissertation. The candidate formed a relationship between lean manufacturing and its predecessors, which comprised mass production and craftsmanship manufacturing. The relationship the candidate formed was characterised by **three dominant manufacturing paradigms**, which the candidate argued are equal to each other and are implied in a **classical technological evolution**.

The candidate will show that the relationship formed between lean manufacturing and its predecessors is embodied in the progress of a technological paradigm along a technology trajectory, which represents a continuum from exploration to exploitation. The candidate will achieve this by considering the automobile as a technological paradigm and evaluating the automobile's technological evolution. Precipitative events that define a classical technological evolution were identified by the candidate, which include a **disruptive origin**, the achievement of a **dominant design** and an **inflexion point** in the trajectory.

The chapter concluded with a table of key steps towards the development of an ambidexterity model by the candidate.

# CHAPTER 4
# ANALYTICAL FRAMEWORK DETAIL

## 4.1 INTRODUCTION.

This chapter details established theory and develops the candidate's new perspective on lean manufacturing that was outlined in Chapter 3 of this dissertation, according to the strategy in Table 3 of this dissertation. The candidate shows that the relationship between lean manufacturing and its predecessors can be evaluated through six dimensions of innovation, which encompass established theory for lean manufacturing, innovation management, behavioural science and economics. The six dimensions of innovation are: (1) Object of change, (2) Degree and frequency of change, (3) Relative time to market, (4) Technological trajectories, (5) Cost dynamics and (6) Relationship to the dominant design.

## 4.2 HARE, TORTOISE AND CROCODILE.

The development of LM is attributed predominantly to Taiichi Ohno[13] (*e.g.* Monden, 1994, p. xvii; Cheng and Podolsky, 1996, p. 2; Mika, 2006, p. 161). Ohno joined Toyota[14] in 1932 as a graduate engineer (Holweg, 2007, p. 434) and became eventually executive vice-president (Toyota Motor Corporation, p. 58). Ohno wrote their text on LM in order to document the implementation of LM at Toyota and to explain LM to outsiders (Ohno, 1988).

### Hare and tortoise.

Ohno drew on a fable about a race between a hare and tortoise to convey the philosophy behind LM. Ohno (1988, p. 63) states: "The Toyota production system can be realized only when all the workers become tortoises". This quote is famous and is regarded to capture the essence of LM. The symbolism is potent, in that the humble and monotonous tortoise can cover the same distance as the hare through the mass accumulation of small and regular steps. Moreover, the tortoise can achieve this without drawing attention to itself. The hare is vastly superior in speed, but is capricious and unreliable. Here, continuous incremental progress succeeds over intermittent bursts of activity. Further, the tortoise can achieve the same end as the hare and in this context, the hare's speed is wasteful. The tortoise can be said to epitomise Toyota and *kaizen*. Stewart and Raman (2007, p. 76) encapsulated Toyota's ascent to market leadership in the Japanese word *jojo*, which means "slowly, gradually and steadily".

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[13] Whilst Ohno is regarded as the pioneer of LM, it was conceived by Toyota Motor Company founder Kiichiro Toyoda before World War 2. 'LM' was called "just-in-time (JIT)" at this time based on Toyoda's concept of "just make what is needed in time, but don't make too much" (Toyota Motor Corporation, 1987, p. 58). Post World War 2, JIT was revived and developed fully by Ohno, who renamed it the Toyota Production System (TPS) (Ohno, 1988). TPS is regarded to have been envisioned by Kiichiro Toyoda after visiting the Ford Rouge plant in 1929 and completed by Ohno in 1971 (Mika, 2006, pp. 146-147). Therefore, it is correct to deem Toyoda as the inventor and Ohno the innovator of LM. The term "lean" manufacturing was coined in the U.S.A. in 1988 by Krafcik, as means of contrasting MP (Holweg, 2007, p. 426). Outside of Toyota the terms JIT, TPS and LM are used interchangeably.

[14] Toyota started as a loom works with 1894 origins and in 1937 the car manufacturing department was split from Toyota Automatic Loom Works and named Toyota Motor Company (Toyota Motor Corporation, 1987, p. 11). Toyota is a deviation from Toyoda, which means large, abundant rice field in Japanese. Toyota does not have a meaning in Japanese (Womack *et al*., 1991, p. 48).

**Hare and tortoise, both eaten by uninvited crocodile.**

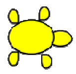
The candidate borrowed and extended Ohno's metaphor to symbolise the dissertation theme. The candidate framed firstly the race between the hare and tortoise as a race of innovation to market. Secondly, the candidate extended the race participants. The candidate believes that in doing so it is possible to symbolise neatly the three Toyota innovation mechanisms.

*Kaizen* identifies with the tortoise and *kaikaku* with the hare in the candidate's metaphor. Whilst they have contrasting approaches, they both compete within an established race. Here, the established race represents a technological paradigm. The candidate added a crocodile to this scenario, which identifies with *kakushin*. The crocodile represents an uninvited and disruptive element, which by playing by its own rules is inconspicuous *in absentia*. The crocodile poses the threat of obliterating both the hare and tortoise through ambush, thus redefining their race and paradigm. Here, the crocodile acts outside of the paradigm that the hare and tortoise act within.

## 4.3 THE NATURE OF TOYOTA INNOVATION MECHANISMS IN DETAIL.

Symbols used in this section will be utilised throughout this dissertation.

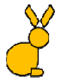
### 4.3.1 *Kaizen* (continuous incremental improvement).



*Kaizen* is a Japanese word, which is translated commonly to "continuous improvement" (*e.g.* Mika, 2006, p. 158; Ortiz, 2006, p. 232). The nature of *kaizen* is described as being conservative (Kondou, 2003, p. 519), constant (Hines, 1996, p. 6), evolutionary (Bessant *et al*., 2001, p. 70), gradual (Imai, 1986, p. 23; Osono *et al*., 2008, p. 10) and incremental through small and relentless improvements (*e.g.* Griffin and Hauser, 1983, p. 2; Imai, 1986, p. 24; Monden, 1993, p. 30; Australian Quality Council, 1994a, p. 4.12; Bicheno, 1994, p. 78; Womack and Jones, 2003, p. 23; Tidd *et al.*, 2005, p. 489; Liker and Hoseus, 2008, p. 156). An important feature of *kaizen* is that it is a process based approach to collective innovation and is not orientated towards results *per se* (Imai, 1986, p. 16). *Kaizen's* strategy is to apply perennial, co-ordinated, process driven and diminutive improvements to all levels and functions within an enterprise, with the intent of aggregate gain. Ohno's (1988) metaphor implies that the continuous accumulation of increments is more successful in the long-run than intermittent, radical changes. Here, *kaizen* challenges the importance placed on "innovation[15]" in Western thinking (Imai, 1986, Chapter 2; Australian Quality Council, 1994a, p. 4-12).

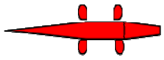
[15] Innovation from an Eastern perspective is explained in Section 4.4.3. (e) Technology-push/customer-pull continuum.

### 4.3.2 *Kaikaku* (radical intermittent change).



*Kaikaku* is a Japanese word, which is translated commonly to "instant revolution" (Harrison, 2000, p. 186). The nature of *kaikaku* is described as conveying a sense of drastic change or reform (Stewart and Raman, 2007, p. 81), radical step-change (EEF, 2001, p. 29), singular events (Browning and Heath, 2009, p. 30) and breakthrough events (Hines *et al*., 2004, p. 1003). *Kaikaku* contrasts *kaizen*, in that a degree of process deviation and interruption to the *status quo* is tolerated, if it enables a platform for future *kaizen* activity.

### 4.3.3 *Kakushin* (disruptive transformation).



*Kakushin* is a Japanese word, which is translated broadly to mean "innovation" (Kondou, 2003, p. 517). Here, the candidate contends that it is important to deconstruct accurately the meaning of innovation from a Japanese perspective. Innovation from a broad Japanese perspective implies a focus on results, intermittent breakthrough and individual enterprise, or the opposite of *kaizen* (Imai, 1986, Chapter 2). Imai's (1986) definition accords with Kondou (2003), who states firstly that *kaizen* is not innovation and secondly that innovation is related to dramatic results. Kondou (2003) defines specifically the process of *kakushin* as the cyclic summation of both innovation activity and *kaizen*, which results in new eras (Kondou, 2003). Here, the candidate contends that innovation from the perspective of Kondou's (2003) definition, can be regarded as *kaikaku* and that it exists within an existing paradigm. Moreover, *kakushin* can be regarded as a new paradigm, in that when the sum of all possible *kaikaku* and *kaizen* activity within an existing paradigm is achieved, a new paradigm emerges through *kakushin*.

## 4.4 SIX DIMENSIONS OF INNOVATION.

The candidate contends that their analytical framework represents the interaction between six dimensions of innovation.

### 4.4.1 Innovation Dimension 1: Object of change.

Innovation is creative intrinsically and can be regarded as being unlimited in object. *E.g.* it can be applied to processes, products, services, systems, behaviours *etc*.

### 4.4.2 Innovation Dimension 2: Degree and frequency of change.

The three Toyota innovation mechanisms were concluded by the candidate to correspond to the three generic innovation mechanisms defined in Table 4 of this dissertation. Here, they are differentiated by their degree and frequency of change. *Kaikaku* is intermittent and radical, *kaizen* is continuous and conservative and *kakushin* is transformational. Transformational innovation implies that it develops outside of existing paradigms and occurs once in any paradigm. Accordingly, radical changes are less frequent than conservative changes and occur within extant paradigms.

The candidate argues in the next sections that it is possible to map the scope of innovation at Toyota by relating its objects of change to their degree and frequency of change.

**Competency enhancing vs. competency destroying.**

An issue that requires resolution is how to categorise the objects of change. The candidate chose to delineate object categories within the context of competency enhancing vs. competency destroying innovation. The object, degree and frequency of innovation are determinants of whether competencies are destroyed or enhanced. Competency destroying innovation renders obsolete existing competencies and in its pure sense is transformational. Competency enhancing innovation builds upon existing competencies within a paradigm. The candidate believes that this framework is appropriate because it reflects the strategic intent and outcome of an innovation. Competency destruction and competency enhancement have different strategic intentions (Schilling, 2005, p. 39) with different distinctly constructs and motivations (Gatignon *et al*., 2002, p. 1120). Here, it is important to differentiate between the strategic intent of an innovation and its outcome for the innovator. *E.g.* transformational innovation by an organisation may be intended strategically to destroy the competencies of its rivals whilst an outcome may be an enhancement of the innovator's competencies (Schilling, 2005, p. 39). Similarly, the strategic intent by an organisation to enhance existing competency in a high-order product concept through an intermittent radical innovation may have the outcome of destroying its competencies in low-order product concepts (Henderson and Clark, 1990, p. 28). Here, it can be said that incumbent[16] organisations with significant investment in competencies are cautious about engaging in competency destroying innovation because of the potential outcome of investment devaluation. Incumbent organisations tend to engage in continuous incremental enhancement of existing best practices with a focus on processes (Clark, 1985; Dosi, 1988; Benner and Tushman, 2003; Teece, 2007, pp. 1327-1328). Incumbents often lead in component innovation because it carries less risk than high-order innovation (Christensen and Rosenbloom, 1995, p. 255). Moreover, incumbents tend to develop relationships with network partners to leverage their knowledge as a source of complementary competency enhancement (Freel and de Jong, 2009, p. 881).

Competency enhancement is fundamentally exploitative, whereas competency destruction is rooted in exploration (Henderson and Clark, 1990, p. 13; March, 1991, p. 85; Levinthal and March, 1993, p. 105; Benner and Tushman, 2003, p. 253; O'Reilly and Tushman, 2008, pp. 189-190).

[16] This dissertation uses incumbent as a broad term connotating "mature, stable, relatively large organisation, operating in a mainstream, commodity market". Its specific meaning is developed progressively in later sections.

**Business model innovation.**

The candidate observed throughout the literature survey that the most far-reaching outcome from innovation occurs at business model level. Tidd *et al*. delineated categories of innovation objects at business model level into organisational paradigm, strategic position, product and process[17]. Innovation at the paradigm and strategic levels impacts the identity, purpose, mindset and strategic posture of the innovating organisation. Innovation at the product level impacts what the innovating organisation offers markets. Innovation at the process level impacts how the innovating organisation delivers its products to market (Tidd *et al*., 2005, p. 13). Innovation at the paradigm and strategic levels is exploratory inherently (Porter, 1996). Here, the outcome for the innovator is competency destroying inherently. Conversely, process innovation is a result of organisation around a defined product (Clark, 1985). Here, the outcome for the innovator is an enhancement of existing competencies. Product innovation can have mixed outcomes of competency destruction and enhancement (Clark, 1985; Henderson and Clark, 1990). Kondou (2003, p. 523) categorised innovation objects as mind, product and process, which accords generally with Tidd *et al*. (2005). The candidate believes that Tidd *et al*. (2005) and Kondou (2003) provide categorisation of innovation object at business model level, which encompasses interdisciplinary and Toyota innovation theories.

**Product innovation.**

The candidate observed that Clark's (1985) framework could be used to provide an avenue for the categorisation of innovation objects within products, which complements the categorisation at business model level. The candidate reasoned that product innovation can be regarded as an intermediary between strategy and process design and should be included in the categorisation because of its pivotal role. The objects of innovation within products is based on a hierarchically nested system, which ranges from the complete product to its individual elements (Schilling, 2005, pp. 39-40). The highest order of product innovation is at paradigm level and the lowest order is component innovation. Architectural innovation of core concepts is an intermediate level (Clark, 1985, pp. 249-250; Henderson and Clark, 1990, pp. 10-13). Here, the outcome for the innovator from high-order innovation is competency destroying inherently. Conversely, the outcome from low-order process innovation is an enhancement of existing competencies. Architectural innovation of core concepts can have mixed outcomes of competency destruction and enhancement.

**Toyota innovation objects and priority.**

Figure 2 represents the object of innovation versus its degree and frequency of change as a matrix. The candidate has positioned Toyota's innovation activity within the matrix according to the results from the candidate's literature survey. The candidate's positioning of Toyota's innovation activity

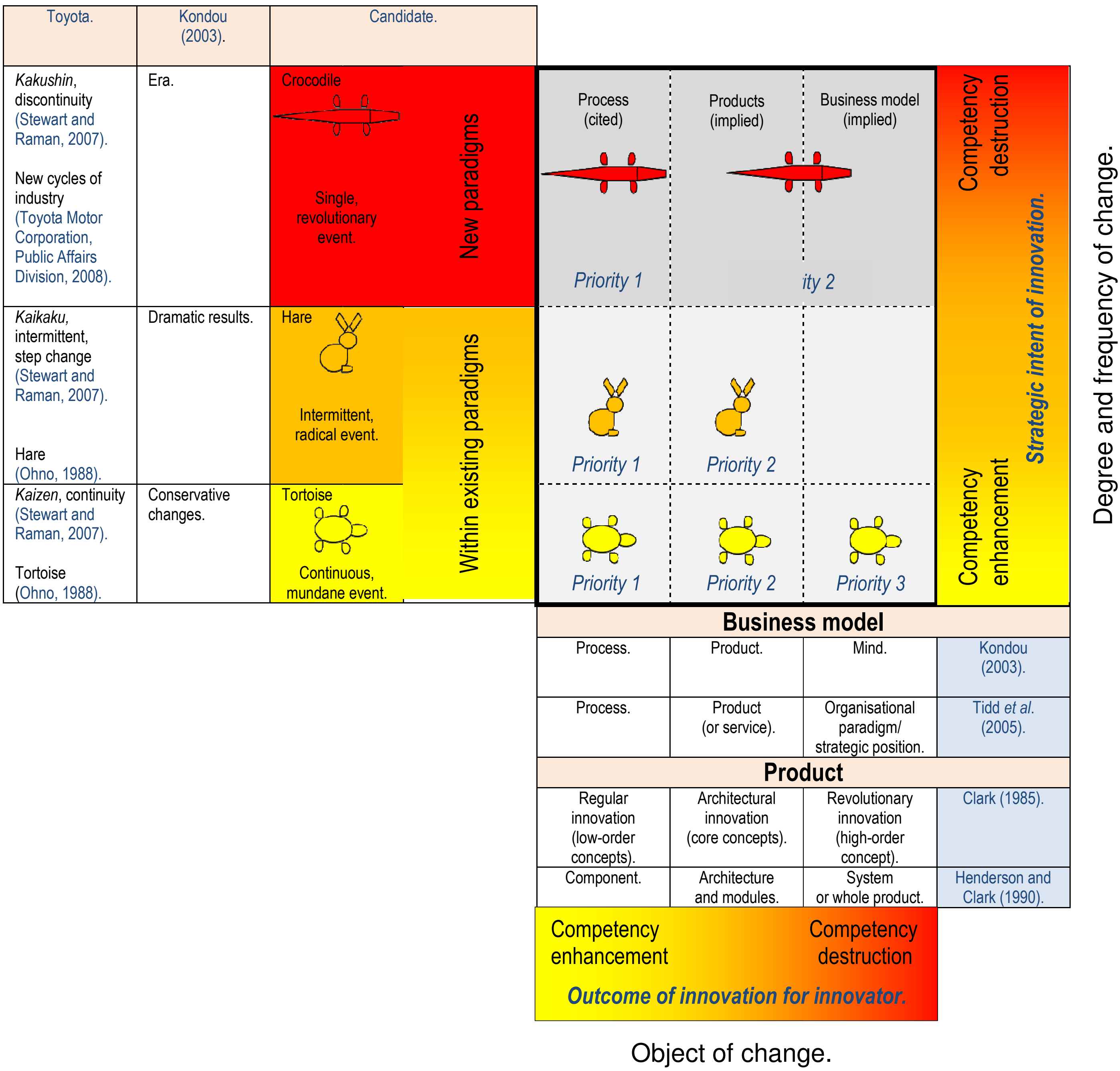
[17] The term process in this dissertation is an all encompassing term that includes systems, procedures, methods *etc*. The exact delineation is expounded as appropriate in proceeding chapters.

within the matrix maps the scope of innovation by Toyota, which can be summarised as follows. Toyota applied consistently competency enhancing continuous incremental innovation to all innovation objects within its enterprise. Toyota's first historical priorities were the objects of manufacturing processes and product components. Its second historical priority was core product concepts and its third was high-order product concepts and enterprise mindset. Toyota also applied historically sporadic and limited intermittent radical innovation where Toyota's first priority was its manufacturing processes and its second was product architecture and core concepts. Here, there is a degree of competency destruction within Toyota, but the overall strategic outcome was competency enhancement within the existing automobile paradigm. Toyota's recent advent of *kakushin* has been cited in the literature as applying to processes[18] and judged by the candidate to be implied at product and business model levels. Here the candidate contends that Toyota's expansion in scope of innovation to objects outside of the existing automobile paradigm and the adoption of a new exploratory mindset contrasts sharply with Toyota's historical approach of *kaizen* because it represents the exploration of new paradigms.

The candidate has confirmed in Figure 2 that Toyota's historical locus of innovation activity was directed fundamentally towards competency enhancing continuous incremental improvement within the existing automobile paradigm, which is consistent with customer-pull. Furthermore, *kakushin* is directed towards transformation and new paradigms, which is inconsistent with customer-pull. Here, the candidate argues that *kakushin* represents an expansion in the scope of Toyota's innovation activity and may be interpreted as exploration beyond Toyota's historical practice of lean manufacturing in the existing automobile paradigm.

[18] *Kakushin* directed towards the innovation object of manufacturing process is planned for Toyota's Takaoke plant. According to Toyota President Watanabe: "The new manufacturing processes at Takaoke will completely change the way Toyota make cars" (Stewart and Raman, 2007, p. 82). Takaoke is intended to be the pilot plant and model for the corporate rollout of the new *kakushin* process technology paradigm (Chappell, 2007, p. 27; Toyota Motor Corporation, Public Affairs Division, 2008, p. 2), which the candidate argues provides clear evidence that *kakushin* is regarded as transformational innovation within Toyota. Whilst the process paradigm at Takaoke is transformational, it still acts fundamentally within the existing automobile paradigm because it is directed towards the manufacture of automobiles. The candidate will show that *kakushin* directed towards new product paradigms and business model paradigms acts fundamentally outside of the existing automobile paradigm.

*Figure 2: Object and priority of innovation at Toyota.*
*Source: Candidate's design.*




## 4.4.3 Innovation Dimension 3: Relative time to market.

Innovation theory agrees that the timing of when to enter, exit or attempt to create a market is a far reaching decision. Many variables must be considered including the innovation strategy, industry structure, consumer behaviour, technical capabilities and economic environment. Here, the candidate builds detailed theory for relative time to market from the fundamentals of technology-push and customer-pull, as a prelude to technology trajectory theory.

#### 4.4.3 (a) TECHNOLOGY-PUSH VS. CUSTOMER-PULL.

Dosi (1982) asserts that technology-push and customer-pull represent extremes, which in their pure sense operate in special circumstances only. Moreover, that the majority of innovation occurs between them. Dosi's assertion can be regarded as a standard perspective (*e.g.* Imai, 1988, p. xxxi; Rothwell, 1992, p. 73; Ortt and van der Duin, 2008, p. 534; Teece, 2008, p. 509; Brem and Voigt, 2009, p. 356; Cetindamar *et al*., 2009, p. 241).

**Technology-push and customer-pull as business models.**

The terms technology-push and customer-pull are used to describe two contrasting approaches to innovation. Shon (1967 cited in Burgelman and Sayles, 1986) describes technology-push as developing new technologies and creating markets for them and customer-pull as exploiting existing market needs and developing technologies to meet them. Innovation theory agrees that innovation is essential to ensure ongoing sustainability (*e.g.* Bianchi and Miller, 1996, p. 193; Tidd *et al*., 2001, p. 17; Teece, 2008, p. 506; Commonwealth of Australia, 2010, p. 1). Technology-push and customer-pull can be regarded as primary business models in this context. Keywords that describe them are shown in Table 11.

*Table 11: Keywords describing technology-push and customer-pull as business models. Source: Candidate's design.*

| | TECHNOLOGY-PUSH | CUSTOMER-PULL |
|---|---|---|
| Dosi (1982, pp. 147-151). | Short-run market independence. Autonomous or quasi-autonomous. | Passive. Reactive. Market forces main determinants of technical change. |
| Kano *et al.* (1984, p. 39). | ---- | Capture voice of customer. Basic, expected and excitement needs. Satisfied customer. |
| Burgelman and Sayles (1986). | Breakthroughs with good commercialisation potential. | Markets with assured demand. |
| Rothwell (1992, p. 73). | 1st generation innovation model. | 2nd generation innovation model. |
| Wonglimpiyarat (2004, p. 230). | Schumpeter approach. | Schmookler approach[19]. |
| Gerpott (2005, cited in Brem and Voigt, 2009, p. 356). | High technological and market uncertainty. Uncertain time to market. Difficult customer R&D integration. Qualitative, discovering market research. Extensive need for change in customer behaviour. | Low technological and market uncertainty. Known time to market. Easy customer R&D integration. Quantitative, verifying market research. Minimal need for change in customer behaviour. |
| Roberts (2007). | Technical state-of-the-art, unanticipated. Breakthroughs. | Continuity. Incremental changes called from existing marketplace. |
| Sandberg (2007, pp. 254-258). | Proactive. Behaviour influencing and modifying. | Reactive. Fulfilment of customer needs. |
| Ortt and van der Duin (2008, p. 525). | Scientific discovery to market. | Customer needs more important than technological progress. |
| Teece (2008, pp. 508-509). | Emphasis on technology, new supply side opportunities and entrepreneurship. Assumes consumer needs. | Neoclassical perspective. Firms anticipate and respond to latent market signals. Assumes an *a priori* need recognition. |
| Brem and Voigt (2009, pp. 355-356). | Technology oriented and induced. Business to business. Creative/destructive. New/major improvement. | Market oriented and induced. Business to consumer. Invent to order. Replacement or substitute. Face-lifting. Incremental innovation |
| Grebel (2009, pp. 301-304). | Novel, not necessarily following economic utility, with economic selection absent. | Utility drives demand. Market selection drives supply side behaviour. |
| Murovec and Prodan (2009). | Benefits from scientific information: research institutes, universities *etc.* | Benefits from market sources of knowledge: customers, competition suppliers *etc.* |
| Dell'Era *et al.* (2010) | Creates new symbolism, meanings and behaviours. Can transform lifestyles and societal values. | Adapts to evolution of existing socio-cultural models. |
| Dosi and Grazzi (2010). | Large changes in procedures and inputs. | Small changes in procedures and inputs. |

[19] Freeman (Freeman 1982, cited in Wonglimpiyarat, 2004, p. 230) associated technology-push with Schumpeter and customer-pull with Schmookler (1962), who was regarded as the post-Schumpeter champion of economic theory.

**Potential limitations.**

Both business models have strengths and weaknesses, depending upon the context in which they are applied. Customer-pull is the most applied model (University of Technology Sydney, 2005, Section 2) and has a greater impact on overall process and product innovation output than technology-push (Murovec and Prodan, 2009, p. 870). Further, it can be argued that customer-pull generates more profit than technology-push (Jansen *et al*., 2006, p. 1671; Roberts, 2007, p. 51; Grebel, 2009, p. 204). Whilst this may provide a persuasive argument for the adoption of customer-pull there is a counter argument, which exploits its weaknesses. Teece (2008, p. 209) argues that customer-pull gives little credit to the roles of technology, new supply-side opportunities or entrepreneurship. Dell'Era *et al*. argue that technology-push has the ability to transform lifestyles and societal values and is a powerful agent in the creation of new socio-cultural languages, meanings and behaviours. Customer-pull in contrast adapts to the evolution of existing socio-cultural models rather than creating new symbolism and meaning (Dell'Era *et al*., 2010). Whilst both models have limitations, neither can be superior. University of Technology Sydney (2005, Section 2) capture this in "Neither technology push or market pull is a "better" strategy. Both have advantages and disadvantages: market pull is less risky, as there is a known market – however technology push has the potential for higher rewards – if a proprietary technology finds a market, this market can be dominated and competition may be non-existent – at least until either patents expire or others have a chance to develop the technology". An example within the automobile paradigm is the development of petrol engines versus the development of electric engines. The development of more efficient petrol engines carries less technological risk than the development of electric engines and has an established market (customer-pull). However, the development of a market leading electric engine may result in greater long-term rewards (technology-push). Table 12 summarises the limitations of both models.

***Table 12: Limitations of technology-push and customer-pull business models. Source: Candidate's design.***

| | TECHNOLOGY PUSH | CUSTOMER PULL |
|---|---|---|
| Dosi (1982). | Can fail to consider intuitive factors in changing economic conditions.<br>Difficult to incorporate contextual complexity and economic long run.<br>High uncertainty. | Passive mechanical and reactive.<br>Assumes pull direction can be known.<br>Relies on market signals/interpretation mechanisms which may be flawed.<br>Incapable of determining why and when alternate technologies emerge.<br>Inventive capability can be neglected.<br>Changing market conditions lack direct relationship. |
| Burgelman and Sayles (1986). | Tough problems encourage applications within existing technical capabilities.<br>Often addresses atypical user.<br>Can become locked into one solution.<br>May require proof of success to secure funding.<br>May encounter resistance and require lobbying and momentum building to succeed. May be dampened by "conventional wisdom". | Needs often described in generalised and indeterminate ways.<br>Tendency to focus on easily identified needs with minor potential.<br>Market-oriented compromises may dilute technology potential.<br>Continual "opportunity" redefinition.<br>May lack champion.<br>Complex problems may have misrepresentative and inaccurate market data. |
| Wonglimpiyarat (2004). | Unstable. | Customers may lack foresight. |
| Roberts (2007, p 43). | Minority of actual innovations.<br>Lack of entrepreneurial champion.<br>Can become "hobbyhorse" driven. | May focus on vocal "lunatic fringe".<br>Market oriented R&D control. |
| Ortt and van der Duin (2008, p. 525). | Inattentive to current processes, current market and professional commercial aspects. Lack of integrated strategic relationships. | Focus on evolutionary incremental improvements at expense of breakthroughs. |
| Teece (2008). | Assumes R&D expenditure results in market and economic gains. | Discredits role of technology, supply side opportunities and entrepreneurship.<br>Assumes known possibilities. |
| Brem and Voigt (2009, pp. 355-356). | Decoupled R&D without structured routine "lab in the woods approach".<br>Tendency to "reinvent the wheel". | Incremental focus on *status quo* increases probability of external threats. Market misinterpretation.<br>Administration processes may be potential driver.<br>Lack of strategic focus |
| Dell'Era *et al.* (2010). | Does not adapt to existing socio-cultural models. | Does not create new meanings, symbols, emotions, socio-cultural values, models and behaviours. |
| Dosi and Grazzi (2010). | Large innovation inputs may not result in corresponding large output. | Small innovation inputs may not result in corresponding small outputs. |

**Techno-economic relationship of technology-push to customer-pull.**

Dosi's (1982) model provides insight into the contexts in which technology-push and customer-pull are most effective. Dosi (1982, p. 147) relates technology-push and customer-pull to "the degree of autonomy of the innovative activity from short-run changes in the economic environment". Short-run is defined as the period where some cost commitments do not end (Baumol and Blinder, 2005, p. 754). Opportunities to change production or other core processes are restricted in the short-run because of incumbent and predetermined structures from past decisions. The enterprise's fundamental parameters are based on a fixed planning horizon and have inescapable commitments. Here, production inputs, which do not rise when outputs rise, behave effectively as fixed costs. *E.g.* dedicated production facilities, plant infrastructure and tenured staff. Conversely, the long-run is the period where all current commitments end. The enterprise is free to reconfigure itself and fixed cost inputs become effectively variable costs (Baumol and Blinder, 2005, pp. 105-106). Dosi (1982) relates technology-push and customer-pull to two phases of an industry's evolution. Technology-push dominates the emergence of new industries through extraordinary technology. Customer-pull dominates in a mature industry where technological innovation is endogenous to the normal economic mechanism[20]. Dosi argues that as an industry becomes entrenched and stabilised, ordered and powerful market forces take hold and shape innovation decisions. A market that operates under a normal economic mechanism is characterised by a cumulative pattern of technological advances, where a producer's innovation decisions are a trade-off between their prevailing economic and institutional characteristics. Conversely, the emergence phase of an industry is characterised by unstable and weak market forces. Here, Dosi argues that technology-push has greater autonomy in innovation activity than customer-pull (Dosi, 1982, pp. 157-158). Whilst technology-push and customer-pull prevail in contrasting economic conditions, it can be argued that both are motivated by the prospect of short-run monopoly and long-run oligopoly, which is defended by barriers to entry (*e.g.* Dosi 1982, p. 158; Ayres and Mori, 1989, p. 340; Benkenstein and Bloch, 1993, p. 21). *I.e.* a protected monopoly allows an organisation to commit fully resources to exploit it in the short-run, but because monopolies are difficult to achieve, being an industry incumbent is a powerful position to hold in the long-run.

Dosi's (1982) model is qualified by contemporary research as an accepted perspective. *E.g.* Grebel's modelling of technological evolution confirms Dosi's concept of autonomy. Grebel finds that in the emergent technology-push phase of an industry, the normal mechanisms of market selection and equilibrating economic forces are absent, suspended or impotent. *I.e.* novelty is not beholden to existing rules. Accordingly, as the novelty is adopted and begins to mature, endogeneity returns as a process of industrial, market and organisational institutionalisation (Grebel, 2009). The techno-economic characteristics of technology-push and customer-pull are summarised in Table 13.

[20] The concept of a normal market mechanism is expounded in proceeding sections.

Through Dosi (1982), it is clear that within a technological paradigm, technology-push precedes customer-pull and that both models represent the extremes of an industry's evolution.

***Table 13: Relationship of technology-push and customer-pull to autonomy of innovation activity and short-run changes in economic environment. Source: Candidate's design, based on* Dosi (1982).**

| | INDUSTRY EMERGENCE PHASE | INDUSTRY MATURITY PHASE |
|---|---|---|
| Primary business strategy. | *Technology-push.* | *Customer-pull.* |
| Dominant innovation activity. | Transformational. | Incremental. |
| Relative autonomy. | High. | Low. |
| Short-run constraints (supply side). | Capital funding and cash flow for enterprise building and meeting growing demand. | High capital investment in enterprise structure and human resource development. |
| Long-run economic environment (demand side). | Early entrants in unstable market pushing for critical mass, tending to stable market with elementary customer expectations. | Stable market with new players under influence of normal economic mechanism, tending to efficiency and saturation with mature and discerning customer expectations. |
| Long-run oligopoly incentives (barriers to entry). | Setting industry benchmarks (product, process and cost).<br>Intellectual capital time buffer.<br>Brand loyalty.<br>Controlling scarce resources.<br>Scope for increasing returns in market share and efficiency.<br>(first mover advantages). | Shifting industry benchmarks.<br>Intimate customer relationships.<br>Operational excellence.<br>Optimised efficiency.<br>Technical superiority.<br>Integrated value chain.<br>Economies of scale.<br>Large sunk costs.<br>Low risk growth.<br>(late mover advantages). |
| Relative ratio of fixed to variable costs. | Low. | High. |

#### 4.4.3 (b) FIRST MOVERS, EARLY FOLLOWERS AND LATE ENTRANTS.

Dosi's (1982) insights imply that there are shifting competitive advantages and disadvantages embedded in the evolution of an industry, which can be exploited strategically through the timing of when a competitor enters or exits an industry. Innovation theory agrees generally on three categories that define the timing of when a competitor enters a market. The categories are first movers (first with new product/service), early followers (early to market but not first) and late entrants (enter when mainstream market forms) (Schilling, 2005, p. 78). The meaning and influence of innovation on consumers is different for each category (Clark, 1985, p. 249). First movers can exploit paradigm redefinition (Christensen and Rosenbloom, 1995, p.255), pioneer and brand status (Kamins *et al*., 2003, p. 830), loyalty and technological leadership (Schilling, 2005, p. 78). First movers enjoy typically protected technological leadership, through a time and skills buffer from intellectual capital leverage, patents, trade secrets *etc*. (Killen, 2005a). Here, first movers can benefit from initial cash flow and the accumulation of financial reserves (Wonglimpiyarat, 2004, p. 231). However, first movers face greater risk from uncertainty and unforseen outcomes, which may create the opposite effect of what is desired (Bates, 2005, p. 344). Early followers can compete through architectural reconfiguration of the product (Suarez, 2004, p. 271), or indeed the entire industry (Jacobides *et al*., 2006, p. 1201). Late entrants can compete through disruptive process technology (Dacko *et al*., 2008, p. 446) and installing barriers to the costs associated with transformational product replacement (Liu and Ozer, 2009, p. 577).

Through Dosi (1982), it is clear that first movers are associated with technology-push and late entrants with customer-pull.

#### 4.4.3 (c) ADOPTER CATEGORIES.

The timing of when to adopt a technology from the consumer's perspective is also categorised in innovation theory. Adopter categories were defined by Rogers (1962 cited in Schilling, 2005, p. 46) and used by Moore (2004, p. 362) to explain the concept of a technology adoption life-cycle. 362). Rogers (1962) and Moore (2004) are accepted as a standard perspective on the relationship of consumer decisions to an industry's evolution (University of Technology Sydney, 2005a). Adopter categories reflect a diffusion process[21] that is a progressive migration of consumer sentiments and attitudes (Bernstein and Singh, 2008 p. 383), which takes into account their cognitive styles and personality profiles (Foxall, 1994, p. S3). The diffusion of innovations is a study of human behaviour (McDonald and Alpert, 2007, p. 421) in the reaction to an innovation (Bianchi and Miller, 1996, p. 194). The characteristics of the adopter categories are summarised in Table 14.

Through Dosi (1982), it is clear that innovator adopters are associated with technology-push and the late majority with customer-pull.

[21] Diffusion processes are expounded in proceeding sections.

*Table 14: Adopter categories.*
*Source: Candidate's design.*

| ADOPTER CATEGORY (Rogers, 1962 cited in Schilling, 2005, p. 46). | KEYWORDS |
|---|---|
| Innovator. | Technology enthusiasts. Gatekeepers (Moore, 2004, pp. 362-364).<br>Adventurous. Comfortable with complexity and uncertainty. Often have large financial resources (Schilling, 2005, p. 46).<br>Creative. Risk taker. Experimenter. Entrepreneurial. Uncontrolling. Receptive. Open minded (Bernstein and Singh, 2008 pp. 384-385). |
| Early adopter. | Visionaries. Influential (Moore, 2004, pp. 362-364).<br>Well integrated and respected in social system. Often opinion leaders (Schilling, 2005, p. 46).<br>Convinced of technical merits, but concerned about market viability. Important link in transforming technology to commodity (Bernstein and Singh, 2008 pp. 384-385). |
| Early majority. | Pragmatists. Evolution rather than revolution mindset (Moore, 2004, pp. 362-364).<br>Frequent peer interaction but typically not opinion leaders (Schilling, 2005, p. 46).<br>Enthusiastic when convinced with strong focus on accelerating development (Bernstein and Singh, 2008 pp. 384-385). |
| Late majority. | Conservatives. Price sensitive and demanding (Moore, 2004, pp. 362-364).<br>Can be sceptical. May have scarce financial resources. Respond to peer pressure (Schilling, 2005, p. 46).<br>Preference for structures, certainty, intense producer/consumer relationship. Dislike waste. Worried about financial risks (Bernstein and Singh, 2008 pp. 384-385). |
| Laggard. | Sceptical and critical (Moore, 2004, pp. 362-364).<br>Decide by experience rather than social network. Sceptical. Expect high performance (Schilling, 2005, p. 46).<br>Resistant to change (Bernstein and Singh, 2008 pp. 384-385). |

#### 4.4.3 (d) TOYOTA'S RELATIVE TIME TO MARKET.

The candidate shows in Chapter 5 that Toyota can be regarded as a late entrant and exhibits the hallmarks of its relative time to market. Several characteristics about late entrant producers and their economic conditions can be defined based on Dosi's (1982) model and Clark's (1985) framework. The mainstream market of late producers behaves according to normal economic mechanisms (Grebel, 2009, p. 301). Late entrant producers are reactive in their innovation focus, in that they respond to customer needs and do influence directly consumer behaviour (Sandberg, 2007, pp. 254-255). The main impetus for technological development by incumbents comes from addressing the interests of existing customers, in which they have typically heavy resource, structural and competency investment (Christensen and Bower, 1996, pp. 215-216). Incumbents are regarded to be economically and culturally poised to detect and react to signals of customer needs (Moore, 2000, Chapter 4). This position is characterised by continuous incremental innovation with a bias to process improvement and product refinement (Anderson and Tushman, 1990, p. 604; Benner and Tushman, 2003, p. 253; Bessant *et al*., 2005, p. 1372; Cesaroni *et al*., 2005, p. 224; Dacko *et al.* 2008, p. 462; Ortt and van der Duin 2008, p. 525; Gerpott 2005, cited in Brem and Voigt, 2009, p. 355; Grebel 2009, pp. 302-303; Magnusson *et al*. 2009, p. 2).

**The Toyota Motor Corporation as an exemplar of exploitative customer-pull.**

Toyota's application of the customer-pull approach is stressed in the literature (*e.g.* Monden, 1994, p. 6; Morgan and Liker, 2006, pp. 27-28; Hines *et al*., 2008, p. 4; Osono *et al*., 2008, p. 45). Toyota first applied customer-pull in manufacturing through a 1948 pilot program in its engine machining shop and by 1950 customer-pull had been extended by policy to Toyota's marketing processes (Cusumano, 1988, p. 34). The customer-pull approach evolves into a complete organisational philosophy and around 1965 became unofficially "The Toyota Way" (Holweg, 2007, p. 428). Toyota publishes internally The Toyota Way in 2001 to make tacit knowledge explicit. Toyota then publishes "The Toyota Way in Sales and Marketing" in 2002, which emphasises the primacy of fulfilling customer needs and listening to what distributors and dealers have to say as source of customer-pulled knowledge (Osono *et al.*, 2008. pp. 158-161). A "Global Knowledge Center" is established in 2002 to train distributors and dealership employees in the enactment of The Toyota Way in Sales and Marketing (Osono *et al.*, 2008. pp. 202-203).

Imai's (1986) temporal relationship between *kaizen* and radical innovation is corroborated by Dosi (1982), in that radical innovation precedes *kaizen*. Here, Toyota's innovation approach is consistent with its relative time to market. The candidate contends that Toyota can be upheld as an exemplar of exploitative customer-pull.

**4.4.3 (e) TECHNOLOGY-PUSH/CUSTOMER-PULL CONTINUUM.**

Ortt and van der Duin (2008, pp. 522-527) explain that innovation theory is no longer based solely on a technology-push, customer-pull or combined approach, but has evolved into a contextual approach. However, research in this area is fragmented. The candidate contends that a technology-push/customer-pull continuum can be used to de-fragment context.

**Toyota, the West, mass production and technology-push.**

Imai influenced[22] greatly former Toyota president Shoichiro Toyoda and Ohno through his role as a consultant to Toyota. Imai is associated strongly with disseminating the practices of *kaizen* and TPS outside of Japan, by being the first to write about them as an integrated package for Western

[22] *E.g.* Toyota began quality circles in 1962 as a key *kaizen* enabler (Australian Quality Council, 1994a, p. 4-12), coinciding with Imai establishing the *Kaizen* Institute (Mika, 2006, p. 147). Imai coined the phrase "go to *gemba*" where *gemba* is the shopfloor (Australian Quality Council, 1994a, p. 4-12), which resonates strongly with the Toyota principle of *genchi genbutsu* "go and see for yourself" (Stewart and Raman, 2007, p. 76). Imai also advocates the use of the "5 whys" problem solving technique (Australian Quality Council, 1994a, p. 4-12), which is a Toyota staple (Ohno, 1988. p. 17; Womack *et al*., 1991, p. 57; Bicheno, 1994, p. 58). *I.e.* to get to a root cause, as why 5 times.

consumption[23]. Imai's work is important because it ties TPS to other key Japanese management principles under a *kaizen* umbrella (Imai, 1986, p. 4). Imai (1986, p. xxix) reflected upon LM and *kaizen* and stated: "If asked to name the most important difference between Japanese and Western management concepts I would unhesitantly say, Japanese *kaizen* and its process oriented way of thinking versus the West's innovation and results oriented way of thinking". This statement is profound in describing the contrasting objectives and approaches of *kaizen* and non-*kaizen* innovation. Imai (1986, p. 23) defines innovation as a "great leap forward" or "one shot phenomenon" approach, which contrasts the *kaizen* "gradualist" approach. Indeed, Imai (1986, p. 23) goes on to assert: "Western management worships at the altar of innovation". Table 15 summarises Imai's (1986) insights. Here, it can be said that Imai's description of Western innovation correlates generally to technology-push. Imai's insights are echoed in contemporary research by Kull and Wacker (2010, p. 228) who found that Asian managers assign a significantly higher level of importance to avoiding uncertainty than Western managers. Moreover, Imai is echoed in contemporary Toyota literature. Liker (2004, p. 252) states: "if it (Toyota) focuses on the process itself, and continual improvement, it will achieve the financial result it desires".

The significance of Imai (1986) is firstly that as revealed in the literature survey, Imai realised that innovation precedes *kaizen*. Secondly, the candidate believes that Imai can be used to form a technology-push/customer-pull continuum because of Ohno's comparison of LM to MP. Ohno (1988, p. 95) cited that LM is the opposite of MP. Ohno's view is found among contemporary LM authors who often describe MP as simply the opposite of LM (*e.g.* Mika, 2006, p. 160). The candidate contends that within the context of Imai (1986) and Ohno's (1988) comparison of LM against MP, it can be understood how MP is associated with technology-push from a Toyota viewpoint. However, the candidate expects to show in Chapter 5 of this dissertation that whilst MP is opposite architecturally to LM and has strong technology-push characteristics, it is not an exemplar of technology-push.

At this point in the creation of a technology-push/customer-pull continuum LM represents the extreme of customer-pull and MP is associated with technology-push. The candidate will show that the extreme of technology-push is not MP, but CR. A continuum can be used to underscore Dosi's (1982) framework. Figure 3 illustrates the candidate's technology-push/customer-pull continuum.

[23] Ohno was the first to publish externally insights into TPS in 1978 but the text was released only in Japanese (Holweg, 2007, p. 434). The English version was released in 1988 (Ohno, 1988), 2 years after Imai wrote about TPS and *kaizen*.

*Table 15: Keywords for the contrasting approaches to innovation: East vs. West.*
***Source: Candidate's design, based on** Imai (1986, Chapter 2).*

| | WEST (TECHNOLOGY-PUSH) | EAST (CUSTOMER-PULL). |
|---|---|---|
| **Focus** | Creativity. | Adaptability. |
| | Technology. | People. |
| | Short-term. | Long-term. |
| | Products. | Production. |
| **Approach** | Results oriented. | Process oriented, |
| | Rugged individualism. | Teamwork and collectivism. |
| | Dramatic, intermittent breakthroughs. | Undramatic continuous improvement. |
| | Invention, new theories. | Conventional know-how and state-of-art. |
| | Functional specialists. | Multi-skilled cross-functional generalists. |
| | Hierarchical communication. | Open communication. |
| | Closed information. | Shared information. |
| | Improvement residing in specialists' domain. | Incentivised, self-autonomous improvement. |

*Figure 3: Confirmed partially technology-push/customer-pull continuum*
*(at dominant manufacturing paradigm level).*
*Source: Candidate's design.*


**4.4.4 Innovation Dimension 4: Technological trajectories.**

Whilst the previous section detailed the characteristics of technology-push and customer-pull and established partially the relative timing of the Toyota innovation mechanisms, it did not explain how technical development occurs *per se*. According to Terwiesch and Ulrich (2008, p. 31): "In most cases, an individual company cannot resist the rise and fall of a technology. Industry lifecycles have underlying trajectories that no amount of smart planning or prudent investment can change". Toyota's market position according to Dosi's (1982) model can be explained fully by embedding the technological trajectory for the automobile paradigm in this dissertation's analytical framework.

**4.4.4 (a) TECHNICAL ADVANCEMENT AND ECONOMIC GROWTH.**

Technical advancement and its primacy to human evolution, economic growth and prosperity, is an accepted tenet (*e.g.* Lopez-Pueyo *et al*., 2008, p. 169; Kaasa, 2009, p. 218). Innovation theory is now core in economic analysis (Verpagen, 1998, p. 1) and a central theme in economic policy making (Szirmai and Verspagen, 2003, p. 361). The dynamics of innovation entail consideration of its technical and economic aspects (Marengo and Valente, 2010, p. 15).

Adam Smith was a pioneer in the discipline of economics and in 1776 argued the role of productivity in the wealth of nations. Smith used language that may be understood by contemporary operations managers. *E.g.* productivity was described in terms of division of labour, time saving, worker dexterity and the invention of machinery (Castle, 1991, p. 8). David Ricardo was another pioneer who in 1817 placed technological progress in the centre of economic growth (Castle, 1991, p. 13). Technological advancement is regarded as a fundamental growth driver in free markets because competition between privately owned firms encourages innovation as a means of gaining competitive advantages over each other (Baumol and Blinder, 2005, p. 272). Innovation is attributed to three growth promoting features in economic theory. Firstly, new technologies create platforms upon which cumulative change can occur. Secondly, new technologies create beneficial public goods. Thirdly, process innovation accelerates demand, by increasing output and reducing product costs (Baumol and Blinder, 2005, pp. 265-268).

Innovation is at the heart of macro-economic growth in economic theory. Dosi's (1982) model can be regarded as representing a micro-economic component (Dosi 1988; Grebel, 2009).

**4.4.4 (b) INDUSTRIAL CYCLES.**

**Waves of creative destruction.**

Joseph Schumpeter is regarded as the "godfather" of the innovation discipline because of his research into how organisations exploit innovation in order to secure competitive advantage (Tidd *et al.*, 2005, p.7). Schumpeter (1942, p. 84 cited in Anderson and Tushman, 1990, p. 606) describes technological patterns, where occasionally there are innovations that: "strike not at the margins of the profits and the outputs of the existing firms, but at their foundations". Schumpeter described these technological patterns as waves of creative destruction, whereby the *status quo* is punctuated by disruptive innovation. Schumpeter believes that these technological discontinuities propel progress and have the capability to create and destroy industries. Here, individual organisations can redefine industries through disruptive innovation, by changing them fundamentally or rendering them obsolete (University of Technology Sydney, 2005, Section 1).

**Three technological eras.**

The candidate relates directly Dosi's (1982) model to Schumpeter (1942) in that a successful innovation will mature in an ordered manner and in turn will be disrupted, resulting in a discontinuity. Here, the candidate regards the continuous disruption of innovations as an overarching order. The candidate indentified in the literature survey that Dosi's (1982) model comprised two broad technological eras, which were developed by other authors to include a third era (Abernathy and Utterback, 1978; Steele, 1997). Here, the candidate agrees with the perspective of three eras in that they represent the evolution of three dominant manufacturing paradigms. The candidate will show in the following sections that the additional third era relates to a more developed understanding of the emergence of a dominant design. Table 16 summarises the major perspectives of technological eras.

Innovation literature explains that whilst a successful innovation can form an industry, there is an underlying industrial lifecycle, wherein serving technologies are displaced by new technologies. The candidate regards Dosi's (1982) model as the full representation of the innovation's technological trajectory, which comprises three dominant manufacturing paradigms that evolve in an ordered manner and are equal to each other.

***Table 16: Major perspectives of technological eras.***
***Source: Candidate's design.***

| | CHRONOLOGICAL ERA | | |
|---|---|---|---|
| Kuhn (1962), cited in Martin (1983, p. 222). | Pre-paradigm stage. | | Paradigm acquisition stage. |
| Utterback and Abernathy (1975). | Uncoordinated process. | | Systemic process. |
| Abernathy and Utterback (1978). | Fluid pattern. | Transitional pattern. | Specific pattern. |
| Dosi (1982). | Paradigm emergence. | | Paradigm maturity. |
| Anderson and Tushman (1990). | Ferment. | | Incremental change. |
| Steele (1997). | Product innovation and engineering domination. | Process improvement and manufacturing domination. | Capital intensity and finance domination. |

**4.4.4 (c) TECHNOLOGICAL PARADIGMS.**

A technological paradigm can be regarded as a specific body of knowledge (Fagiolo and Dosi, 2003, p. 240) that explains what a technology is and how it operates (Dosi and Grazzi, 2010, p. 180). A technological paradigm defines its own concept of progress based on its inherent technological and economic trade-offs (Dosi, 1982, p. 148). Paradigms are complex artefacts, made of technically bound components and organisational routines (Dosi and Grazzi, 2010, p. 175), which reflect consumer symbolism, meaning, language and emotional characteristics (Dell'Era *et al.*, 2010; Witt, 2010).

The automobile can be regarded as a technological paradigm.

**4.4.4 (d) TECHNOLOGICAL TRAJECTORIES.**

Technological trajectories are specific development paths of technological opportunities (Andersen, 1998, p. 13), which define the direction of advance for a technological paradigm (Dosi, 1985, p. 148). The concept of a technological paradigm progressing along a technological trajectory reconciles technology-push with customer-pull (Grebel, 2009, p. 304).

**Endogenous growth.**

Technological advances become endogenous to the normal market mechanism during industrial maturity of a technological paradigm. Innovation generation, exploitation and diffusion become embedded in a pattern of oligopolistic competition (Dosi, 1982, pp. 157-158). The industry behaves according to a self-regulating mechanism of collective adjustment (Bianchi and Miller, 1996, p. 195) in the presence of normal economic utility and market selection mechanisms (Grebel, 2009, p. 301). Endogenous growth is associated with customer-pull.

**Exogenous growth**

Exogenous growth does not follow necessarily normal economic utility or is dependent on market selection mechanisms (Grebel, 2009, p. 301). The exogenous appearance of a disruptive paradigm may be of no direct economic value in itself, yet if adopted it may trigger endogenous growth (Justman, 2004, p. 201). Exogenous growth is associated with technology-push, as a precursor of customer-pull.

The automobile can be regarded as having traversed a technological trajectory because it had exogenous disruptive technology-push origins and migrated through ordered technological eras to an endogenous customer-pull market.

**4.4.4 (e) S-CURVES FOR TECHNOLOGICAL DEVELOPMENT.**

Technological development is shown frequently to follow an S-curve trajectory (Schilling, 2005, p. 41). S-curves can be regarded as a default perspective of technological development (*e.g.* Becker and Speltz, 1983; Nicholls and Roslow, 1986; Brown, 1992; Abraham and Knight, 2001; Terwiesch and Ulrich, 2008; Talonen and Hakkarainen, 2008). S-curves can be used as an innovation management tool to predict and exploit disruptive change. Nicholls and Roslow (1986, p. 62) capture this: "It enables an entrepreneur to predict the likely stages of growth and maturity of an innovation. This is crucial information for planning the timing of capital requirements, labor force recruitment, promotional efforts, distribution channels, target market(s), and pricing". The use of S-curves for technological forecasting and planning is increasing (McGahan *et al.*, 2004, p. 7; Roberts, 2007, p. 49).

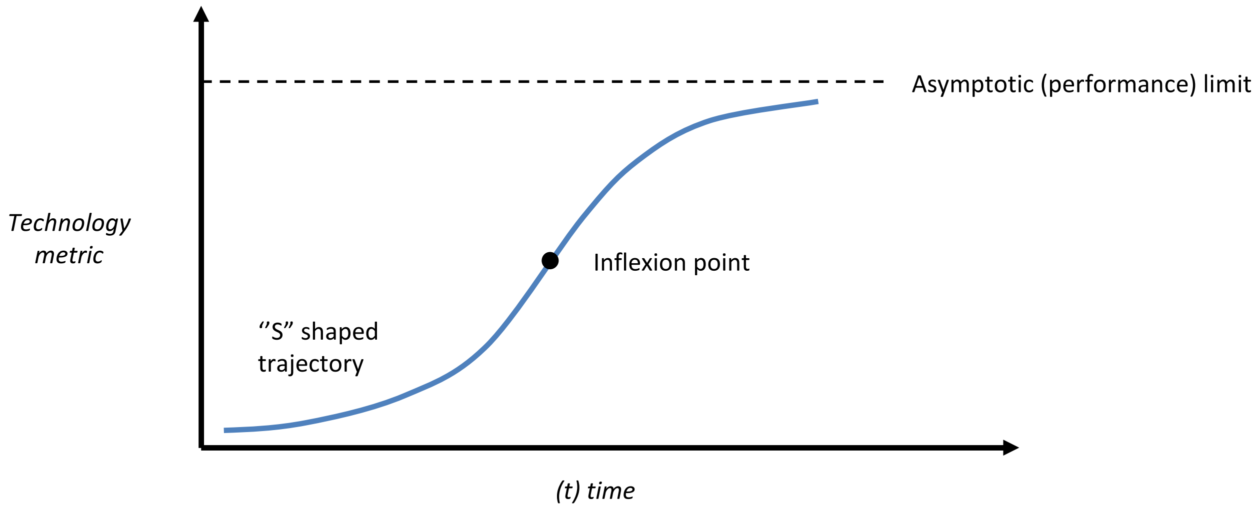
**Inflexion point and asymptotic limit.**

S-curves are characterised by an inflexion point and asymptotic limit. The inflexion point signifies transition from growth to decline (Terwiesch and Ulrich 2008, p. 31) and exploration to exploitation (Adler *et al*, 2009). Here, the candidate argues that the inflexion point marks a fundamental shift from technology-push to customer-pull. The asymptotic limit identifies the performance limit for the technology (Talonen and Hakkarainen, 2008, p. 58). The returns from innovation diminish as technological development approaches the asymptote, to a point of pragmatic saturation.

Technology that approaches its performance limit is regarded to be vulnerable to disruption from a discontinuous paradigm(s).

The nature of S-curves is captured by Schilling (2005, p. 49): "each new S-curve ushers in an initial period of turbulence, followed by rapid improvement, then diminishing returns, and ultimately is displaced by a new technological discontinuity. The emergence of a new technological discontinuity can overturn the existing competitive structure of an industry, creating new leaders and new losers". Figure 4 shows S-curve features.

***Figure 4: S-curve for technological development.***
***Source: Candidate's design, based on** Schilling (2005, pp. 41-47).*




**Technology and time metrics.**

Technology metrics (y-axis) can have the broad definition of technical advance (*e.g.* concrete displacing piled stones) or a specific definition with a discrete performance metric (*e.g.* noise vacillation for power-folding external rear view car mirror). The time domain (x-axis) is defined typically in a holistic sense as overall effort, or specifically as elapsed time, cumulative research and development expenditure *etc*.

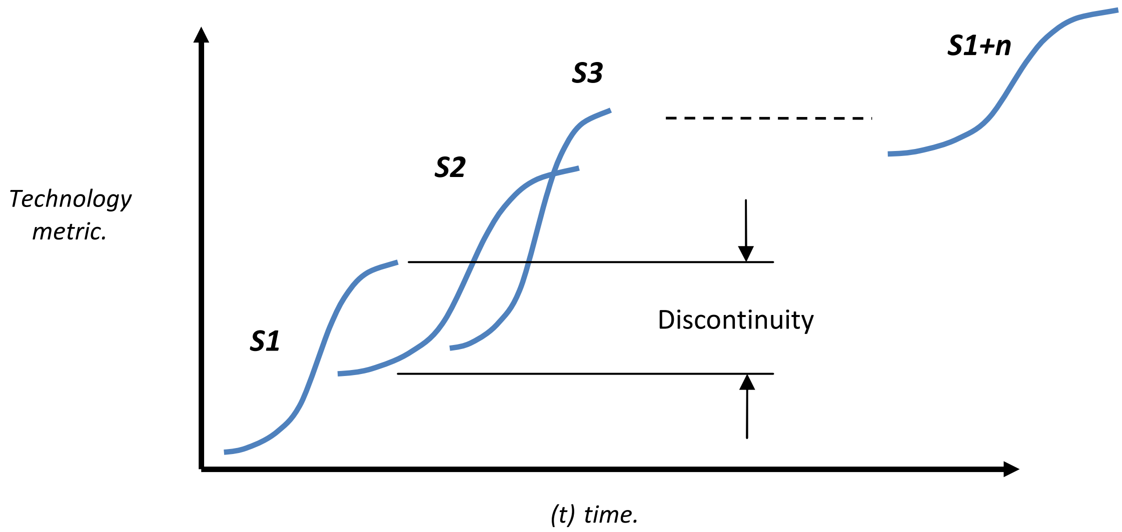
**Disruption.**

S-curves for technological development can be used to map Schumpeter's waves of destruction, in that an initial S-curve (S1) is disrupted by a destabilising technology (S2) and continues (S1+n) (Brown, 1992, p. 64). An example of disruption within the automotive industry is the carburettor[24]. Carburettors were cheap, reliable and provided customer satisfaction. Fuel injection succeeded rapidly in transforming the industry despite demanding initially a premium price (Utterback and Acee, 2005, pp. 12-14). Whilst Dosi's (1982) framework defined the full trajectory of a technology, Schumpeter's waves of destruction imply that a technology may not reach its full potential.

[24] The dissertation will explain in proceeding sections that architectural and component levels in the design hierarchy can be regarded as being sub-paradigm. Here, carburettors are a sub-paradigm architectural core concept within the automobile paradigm.

Moreover, subsequent S-curves are unlikely to be uniform and may overlap. The steepness and performance limits of individual S-curves shape the balance between the return in investment for a new technology and investment in the incumbent technology (Paap and Katz, 2004, p. 16; Schilling 2005, pp. 43-44). *E.g.* in Figure 5, S2 has a significantly higher performance limit than S1 and can destabilise the industry because it creates a discontinuity. S3 has a modestly higher performance limit and steeper slope than S2 and could be adapted by the industry.

***Figure 5: S-curves mapping waves of destruction.***
***Source: Candidate's design based on*** (Christensen, 1992a and 1992b: Schilling, 2005, pp. 43-44).




**Retrospective application.**

S-curves for technological development are used typically for forecasting into the future. The literature reports potential limitations[25] in the use of S-curves for forecasting technological development. The candidate believes that the potential limitations do not apply to this dissertation because the candidate will apply retrospectively the theory for S-curves to the automobile paradigm in order to establish the automobile paradigm's disruptive origin and inflexion point.

The candidate's literature survey revealed that the S-curve trajectory for technological development is appropriate for the automobile paradigm. The candidate expects to show that the automobile paradigm's disruptive origin and inflexion point represent a classical technological evolution.

[25] Potential limitations include: inadequate marketing intelligence, planning horizon, capital investment, cash flow *etc.* (Tidd *et al.*, 2005, p. 278); constancy of effort, research and development intensity and intellectual capital manipulation (Tidd *et al.*, 2005, p. 354); uncontrollable external factors such as regulations, environmental factors *etc.* (Schilling, 2005, p.45); variation at generic component level (Christensen, 1992b); unforseen disruptive technologies (Schilling, 2005, pp. 41-44); capabilities, resources, strategic fit and diffusion rate.

#### 4.4.4 (f) S-CURVES FOR TECHNOLOGICAL DIFFUSION.

S-curves for technological development describe the technical advance and maturation of an innovation and S-curves for diffusion describe the complementary process of the innovation's adoption. Technological development and technological diffusion are cumulative processes, which are interrelated and compound each other. Performance improvements accelerate diffusion and diffusion accelerates investment in further development or *vice versa* (Schilling, 2005, p. 41). The strategic intent to develop a technology achieves the same end as the strategic intent to diffuse it (Geroski, 2000, p. 623). Here, the candidate observed that the techno-economic process of technological advance is tied to the socio-technic process of adoption.

**Socio-technic process.**

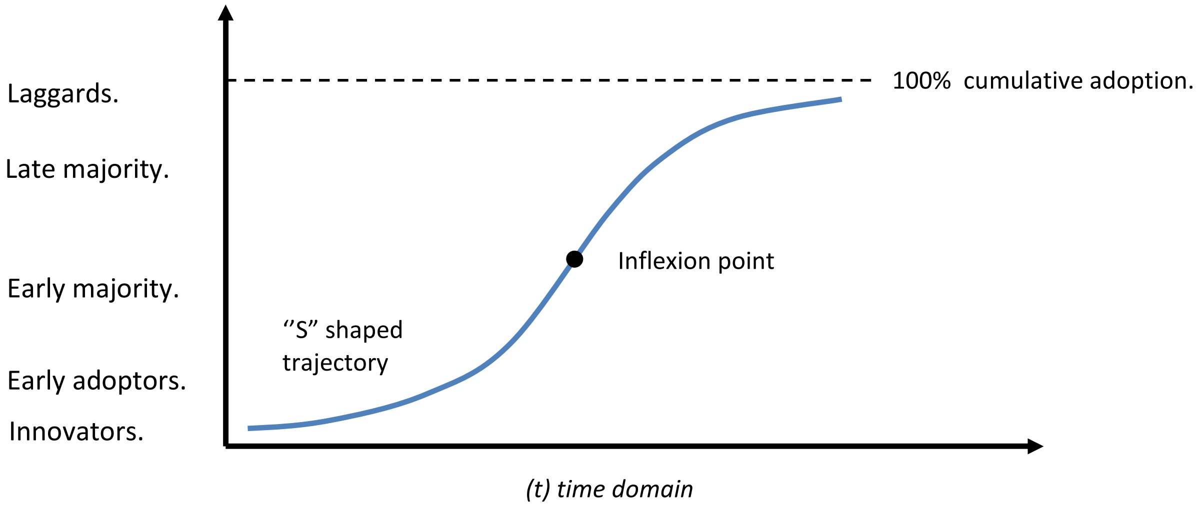
S-curves for technological diffusion reflect the adoption of an innovation throughout various adopter categories and their behaviour towards the innovation (Moore, 2004; Schilling, 2005). S-curves for technological diffusion embody increasing knowledge and product awareness from technological proliferation and use. Product awareness results in more discerning needs and increased consumer purchasing power (Clark, 1985; Dosi, 1988; Grebel, 2009). The modelling and exploitation of consumer behaviour is a fundamental goal in marketing science. *E.g.* in 1959, Forrester published a product life cycle model that tied together the key elements of new product introduction, technical performance, differentiation, market growth, maturity and decline with advertising expenditure and profitability (Forrester, 1959, p. 108). Forrester's model was largely qualitative and later pioneers used mathematical modelling in diffusion research. Key figures including Fourt and Woodlock (1960) and Haines (1964) found that technological diffusion was characterised by exponential growth to an asymptote, which laid the foundation for the basic S-curve (Fourt and Woodlock, 1960; Haines, 1964 cited in Bass, 1969, p. 215). These early models were refined as the effects of social factors such as personality type, information and communication flow, network dynamics *etc.* were incorporated (*e.g.* Bass, 1969). S-curves for technological diffusion are accepted as a standard perspective in contemporary diffusion research (Bass, 2004, p. 1835) and have a history of being used in the formulation of marketing strategies (*e.g.* Brown, 1992; Foxall, 1994; McDonald and Alpert, 2007, pp. 421-425).

**Relationship to adopter categories.**

The adopter categories defined in Table 14 of this dissertation relate directly to the S-curve for technological diffusion (Schilling, 2005, pp. 46-47). Figure 6 shows the S-curve for technological diffusion, which represents the cumulative adoption[26] of an innovation.

[26] The alternative is to represent technological diffusion as a normal curve, which represents the % of market share per adopter category (Schilling, 2005, p. 47). Rogers (1962) assigned percentages to each adopter category. *E.g.* early majority are 34% (Rogers, 1962 cited in Schilling, 2005, p. 46). However Roger's figures have been challenged as a purely statistical derivation (*e.g.* McDonald and Alpert, 2007, p. 422). The candidate recognises that the S-curves for technological development and diffusion may not coincide temporally. The candidate believes that this is not an impediment because this dissertation regards adopter categories as general indicators.

*Figure 6: S-curve for cumulative adoption.*
*Source: Candidate's design, based on* Schilling (2005, pp. 46-47).




**Adoption chasm.**

The creation of a mainstream market[27] depends upon an innovation crossing successfully the adoption chasm (Moore, 2004, p. 364). The chasm is a critical juncture, where an often threatening new technology must win over conservative, pragmatic, sceptical and critical adopters to gain a foothold in a market. Early market adopters play a vital role[28] in the crossing of the adoption chasm and for this reason are a key subject of marketing strategies (*e.g.* Urban and von Hippel, 1988; Foxall, 1994; Moore, 2004; McDonald and Alpert, 2007).

**Retrospective application.**

S-curves for technological diffusion are used typically for forecasting into the future. The literature reports potential limitations[29] in the use of S-curves for forecasting technological diffusion. The candidate believes that the potential limitations do not apply to this dissertation because the candidate will apply retrospectively the theory for S-curves to the automobile paradigm.

The candidate's literature survey revealed that the S-curve trajectory for technological diffusion is appropriate for the automobile paradigm. The candidate expects to show that the automobile paradigm's adopter categories and adoption chasm represent a classical technological evolution.

### 4.4.5 Innovation Dimension 5: Cost dynamics.

Changes in the cost dynamics on the producer's (supply) side and consumer's (demand) side provide a powerful tool for understanding how an innovation evolves. Insights into the strengths, weaknesses

---

[27] Mainstream market is defined as early majority, late majority and laggard adopters. Innovator and early adopters are known as the early market (Moore, 2004, p. 365).

[28] Innovators and early adopters generate cash flow, promote the product and develop market leader image and positive brand perception (McDonald and Alpert, 2007, pp. 426-430). Innovator adopters can also contribute to product development (Urban and von Hippel, 1988, pp. 569-570).

[29] Potential limitations include: information diffusion rate in that information about an innovation diffuses often quicker than the innovation itself (Schilling, 2005, p. 44); the complexity of social factors from unhomogeneous inherently nature of adopters (McDonald and Alpert, 2007, p. 431); unforseen variations in population growth and decline; chasm status.

and migration of the dominant manufacturing paradigms can be gained by examining the relative shifts of strengths and weaknesses within the context of a technological trajectory. This dissertation uses cost metrics from an accounting sense and also includes cost metrics that encompass the behavioural aspects of technological diffusion.

**Product cost.**

The costs of producing a product are a key factor in technological diffusion. Product costs from the producer's perspective include their conversion cost (cost to convert direct materials into finished goods), inventory cost (full production cost) and product cost (full production cost + profit) (Anthony *et al*., 2004, pp. 548-550). Product costs from the consumer's perspective are related to the total utility derived. The concept of total utility is expounded in Section 6.4.4 Value creation in this dissertation.

**Opportunity cost.**

Whilst product cost is the actual cost of producing or purchasing a product, the true cost is regarded to be the opportunity cost. Opportunity cost is the cost of the next best alternative that is foregone in a purchase decision (Baumol and Blinder, 2005, p. 68). The significance of opportunity cost is that it reflects a purchase decision in a holistic and strategic sense and in doing so provides insight into the behavioural aspects of purchase decisions.

Opportunity cost from the producer's perspective encompasses their strategic considerations of capital investment, sunk cost, research and development, technological and market opportunity *etc*. Opportunity cost from the consumer's perspective reflects the goods, services and activities that must be forgone. *E.g.* by investing in specialised plant equipment, a producer may forego the opportunity to produce diverse products and expand its product portfolio. A consumer may purchase a house at the expense of owning bonds.

**Cost of doing business.**

The cost of doing business from the perspective of this dissertation is regarded to be the waste that is tolerated in the achievement of a strategic objective. This concept is expounded in proceeding chapters in this dissertation.

**Utility.**

Utility relates to the consumer's willingness to pay and will be expounded in Section 6.4.4 Value creation in this dissertation.

### 4.4.6 Innovation Dimension 6: Relationship to the dominant design.

According to Anderson and Tushman (1990, p. 604): "Technological breakthrough, or discontinuity, initiates an era of intense technical variation and selection, culminating in a single dominant design. This era of ferment is followed by a period of incremental technical progress, which may be broken by a subsequent technological discontinuity".

The candidate's literature survey identified that the formation of a dominant design is a precipitative event in a technological trajectory. The candidate asserts that CR, MP and LM are centred fundamentally on the formation, emergence and development of the dominant design and have an equally dominating role. The retrospective application of S-curves for technological development and diffusion should reveal the automobile paradigm's dominant design and the candidate's asserted relationship between CR, MP and LM.

#### 4.4.6 (a) DOMINANT DESIGNS AND THE EVOLUTION OF AN INDUSTRY.

The concept of a "dominant design" (Utterback and Abernathy, 1975, p. 644) is a fundamental milestone and transition point in the evolution of an industry (Suarez and Utterback, 1995, p. 416). Whilst the emergence of a disruptive technological paradigm signifies a potential new trajectory, the achievement of a dominant design is a prerequisite for mass adoption and volume production (Anderson and Tushman, 1990, p. 615). The formation of a dominant design and the crossing of its adoption chasm are interrelated, in that they mark an irreversible change of emphasis from technological to market factors (Suarez, 2004, p. 282). A dominant design is a single product architecture that dominates a product class as an industry standard[30] and remains dominant until the next technological discontinuity (Anderson and Tushman, 1990, pp. 604-614).

**Dominant designs as an enabler.**

A disruptive innovation that is not protected by intellectual property barriers and has the potential to displace existing technological paradigms results typically in multiple producers competing for superiority in the new paradigm (Anderson and Tushman, 1990, pp. 610-611). Competition for superiority represents the formative phase of the dominant design, which is characterised by competing product configurations with varied, fragmented and potentially incongruent performance criteria (Suarez and Utterback, 1995, p. 418). The formative phase of the dominant design can be regarded as a strategic race to establish an industry standard (Soh, 2010, p. 438). An industry standard reduces uncertainty in the consumer's understanding of the new paradigm and allow producers to manufacture interchangeable parts through efficient processes (Anderson and Tushman, 1990, p. 614). Moreover, an industry standard enables stable relationships with industry partners and complementors and the ability to co-specialise (Jacobides *et al*., 2006, p. 1205; Teece,

[30] A dominant design can be a *de facto* (Soh, 2010, p. 438) or regulatory standard (Schilling, 1998, p. 271).

2007, p. 1332). The emergence of a dominant design can be regarded to be an enabler, which allows its industry to coalesce around it and enhance its competencies (Schilling, 1998, p. 269). The dominant design for a paradigm is instrumental in the crossing of its adoption chasm and is characterised by its producers and consumers accepting a package of relatively well understood concepts in order to reduce risk and uncertainty. Here, an emerged dominant design becomes a specific artefact that is poised for replication, modification and improvement over time (Dosi and Grazzi, 2010, p. 180). The emergence of a dominant design stabilises its industry and shifts the terms of competition. High-order and core design concepts are fixed fundamentally (Dorf and Byers, 2005, p. 82) and there is scant re-visitation or re-evaluation in subsequent designs (Henderson and Clark, 1990, p. 14).

A dominant design fixes high-order and core design concepts, which provides a stable platform for its industry to develop upon.

**4.4.6 (b) DOMINANT DESIGNS AND EFFICIENCY.**

A dominant design results in the synthesis of concepts into a specific design path, which converges upon the requirements of a typical consumer (Suarez and Utterback, 1995, pp. 416-418). An emerged dominant design reflects a compromise[31] between technical, regulatory and social constraints (Anderson and Tushman, 1990, p. 617). Dominant designs are inefficient inherently and lag behind the industry's technological frontier (Anderson and Tushman, 1990, p. 604). Inefficiency arises from the need to forego extreme technical performance in securing a pragmatic arrangement to reduce technological uncertainty (Suarez and Utterback, 1995, p. 416) and a stable platform for the development of complementors (Schilling, 2005, p. 57). Moreover, the self-reinforcing mechanisms of compatibility pressures, co-specialised complementors, industry regulations and increasing returns from adoption often result in an inferior technology succeeding over superior options (Schilling, 1998, p. 270). Here, the candidate asserts that an emerged dominant design facilitates future product improvement and process productivity through its inefficiency.

Whilst a dominant design encapsulates revolutionary technological advancement, the formation and emergence of its future customer needs occurs in an evolutionary manner (de Heer *et al*. 2002, cited in Sandberg, 2007, p. 255). Improvement opportunities are revealed as producers and consumers gain experience with the dominant design, through "learning by doing" (Anderson and Tushman, 1990, p. 614) and the dissemination of knowledge throughout the industry (Balasubramanian and Lieberman, 2010, pp. 411-412). The more the technology is used, the more it is developed (Schilling,

[31] Forrester (1959, p. 108), a pioneer in marketing science inadvertently summarised the achievement of a dominant design: "Competing products differ only slightly because of agreement among almost all companies on best design methods. Tendency to copy competing features. Demands of mass production to reduce product diversity. Attempts to make all products appeal to the "average'' customer".

1998, p. 270), resulting in cumulative learning effects and the manifestation of a learning curve for cost reduction and waste elimination (Schilling, 2005, p. 58).

The candidate asserts that an emerged dominant design is inefficient inherently and submits that its inefficiency can be exploited as a source of competitive advantage in the future.

**Dominant designs as a catalyst for hierarchical innovation and manufacturing reconfiguration.**
A dominant design enables reconfiguration of the dominant manufacturing paradigm by delimiting the era of ferment with one of continuous improvement (Anderson and Tushman, 1990, p. 606). The emerged dominant design is a crystallising event in the evolution of an industry, in that the organisation of manufacturing systems reflects and embeds the dominant design in its producers' practices, procedures and systems (Henderson and Clark, 1990, p. 15). An emerged dominant design signifies acceleration in process development and a diminishing rate of product innovation (Clark, 1985, p. 247). The architecture of the dominant design increasingly shapes and becomes interrelated with the architecture of its manufacturing systems (Christensen *et al*., 2002, p. 965). Product and market development follow a course of path dependent evolution as the dominant design becomes embedded firmly in organisational processes and customer experience (Rose-Anderssen *et al*., 2005, p. 1104). The stabilisation of high-order and core product concepts results in a tendency to mutate low-order concepts and develop product variants and options (Frenken, 2006, p. 299). Here, the candidate contends that advanced development of the dominant design provides the opportunity for further reconfiguration in the dominant manufacturing paradigm on the basis of achieving full efficiency. The candidate's contention is aligned with the known pattern of a shifting innovation locus from product to process, according to hierarchical product design (Utterback and Abernathy, 1975; Abernathy and Utterback, 1978; Clark, 1985; Anderson and Tushman, 1990).

The emergence of a dominant design shifts fundamentally the focus of innovation to process efficiency and low-order product refinement. The candidate has argued that the development of a dominant design has three phases, which represent the three dominant manufacturing paradigms. The candidate's contention of three phases in the development of a dominant design is summarised in Table 17.

*Table 17: Migration in innovation focus through three phases of dominant design development. Source: Candidate's design.*

| | | *Dominant design phase.* | | |
|---|---|---|---|---|
| | | **FORMATION** | **EMERGENCE** | **DEVELOPMENT** |
| **PRODUCT** | High-order paradigm innovation. | X | | |
| | Core concept architectural innovation. | | X | |
| | Low-order component innovation. | | | X |
| **PROCESS** | Process organisation. | | X | |
| | Process efficiency. | | | X |
| | | **CRAFTSMANSHIP** | **MASS PRODUCTION** | **LEAN MANUFACTURING** |
| | | *Compatible manufacturing paradigm.* | | |

#### 4.4.6 (c) POSITIVE CONSUMPTION (NETWORK) EXTERNALITIES.

The emergence of a dominant design and the crossing of its adoption chasm is related closely to the formation of a broader technological network (*e.g.* Schilling 1998, p. 269; Soh, 2010, p. 438). Here, an industry can develop around the technology, which provides increased benefits to all members (Lange *et al*., 2001, pp. 29-30) through a self-reinforcing feedback mechanism (Schilling, 1988, p. 283). A broader technological network with mutual benefits is characterised by complementary goods, where an increase in the quantity consumed of one good increases demand for the other goods (Baumol and Blinder, 2005, p. 92). Complementary goods result in positive consumption of the dominant design through "network externalities" (Katz and Shapiro, 1986, p. 823). Network externalities promote positive consumption through increasing returns to scale (Katz and Shapiro, 1986, pp. 822), co-specialised assets (Schilling, 1998, p. 270), increasing returns on adoption (Schilling, 1998, p. 270) and increasing advantages from having the dominant design (Schilling, 2003, pp. 17-18). Moreover, technological overspill from complex and technologically intense products can have beneficial effects across industries (Lopez- Pueyo *et al*., 2008, p. 169) and the broader society[32] (Freel and de Jong, 2009, p. 875), with the potential to influence national economies (Nakagawa *et al*., 2009, p. 5).

**Installed base and strategic externality manipulation.**

Strategy can play a pivotal role in building an installed base and creating positive consumption externalities (Schilling 2003, p. 20). An installed base is the number of users a technology has (Schilling, 2005, p. 60). A new technological paradigm can benefit from exploiting coherent externalities and regulatory mechanisms (Bartezzaghi, 1999, p. 247), thereby influencing its market

[32] Here, marginal social benefit exceeds marginal private benefit (Baumol and Blinder, 2005, p. 236).

receptivity (Dacko *et al*., 2008, p. 458). Network externalities can create a social structure that facilitates communication, promotion and "market buzz" (Dacko *et al*., 2008, p. 459) whilst regulatory mechanisms such as standards, legislation and patents can lock-out competitors (Schilling 1998, pp. 267-268). The establishment of a dominant design by an enterprise as an industry standard results in tremendous competitive advantage (Wonglimpiyarat, 2004, p. 248). An enterprise that establishes an industry standard can become an information gateway and industry entrance node (Soh, 2010. p. 455), which allows the enterprise to control and limit technological overspill to competitors (Faems *et al*., 2010, p. 4).

Positive consumption (network) externalities are a powerful agent in the reinforcement of a dominant design.

**4.4.6 (d) COMMODIFICATION.**

The candidate argues that the contemporary automobile paradigm can be regarded as a commodity. A commodity in economic theory is regarded as a normal good where demand for it increases when consumer incomes rise. An inferior good is one where demand for it decreases when consumer incomes rise (Baumol and Blinder, 2005, p. 71). The automobile paradigm crossed its adoption chasm, spread to a mainstream market and developed a massive global installed base. The proliferation of the automobile relegated substitutes such as the horse, bicycle, steam vehicles *etc.* to the status of inferior goods. The contemporary automotive industry can be regarded as serving a commodity market that is dominated by oligopolistic incumbents (Ayres and Mori, 1989 p. 340). Automobile producers compete in "brutally competitive markets dominated by well-informed and highly demanding customers" (Feigenbaum, 2002, p. 49). The development of efficient manufacturing systems is at the point where the automobile paradigm is suited to LM (Mason-Jones *et al*., 2000, p. 4064). Producers using LM are able to enjoy the advantages of customer integration in product customisation (Franke *et al*., 2008, p. 555) and diverse product variants tailored to specific market segments (Terwiesch and Ulrich 2008, p. 31).

**The automobile's progress from hedonic scarcity to utilitarian commodity[33].**

The contemporary automobile paradigm constitutes a transformation from the millennia entrenched socio-cultural model of horse-drawn personal transportation to one with new meaning, language, values and behaviours (Dell'Era *et al*., 2010). The automobile is regarded as a socially agreed and approved consumption symbol in advanced economies (Witt, 2010, p. 17), which is nested in an ecosystem of established complementors[34] (Burgelman, 2002, p. 341). The automobile's historical co-evolution with consumers and the contemporary customisation capability of producers provides a deepening lure in its commodity status (Thrift, 2006, p. 279). Modern automobiles provide a solid

[33] The automobile paradigm's progress is expounded in Chapter 5 of this dissertation.
[34] The automobile paradigm's complementors are defined in Chapter 5 of this dissertation.

knowledge base for facilitating diffusion amongst prospective users by being a self-embodied piece of capital equipment, which allows ease of learning in the core technology, options and complementors (Cohen and Levinthal, 1990, pp. 148-149). Whilst the automobile is now a commodity, the converse applies for its origin. Automobile Year (1982) explain that the first automobiles were scarce and confined to aristocratic “carriage folk”, wealthy novelty seekers and enthusiasts. Here, the candidate submits that the adoption of the automobile in its origins is consistent with the theory presented in this chapter for adopter categories.

The candidate submits that the commodity market of the contemporary automobile is opposite to the market of its disruptive origin.

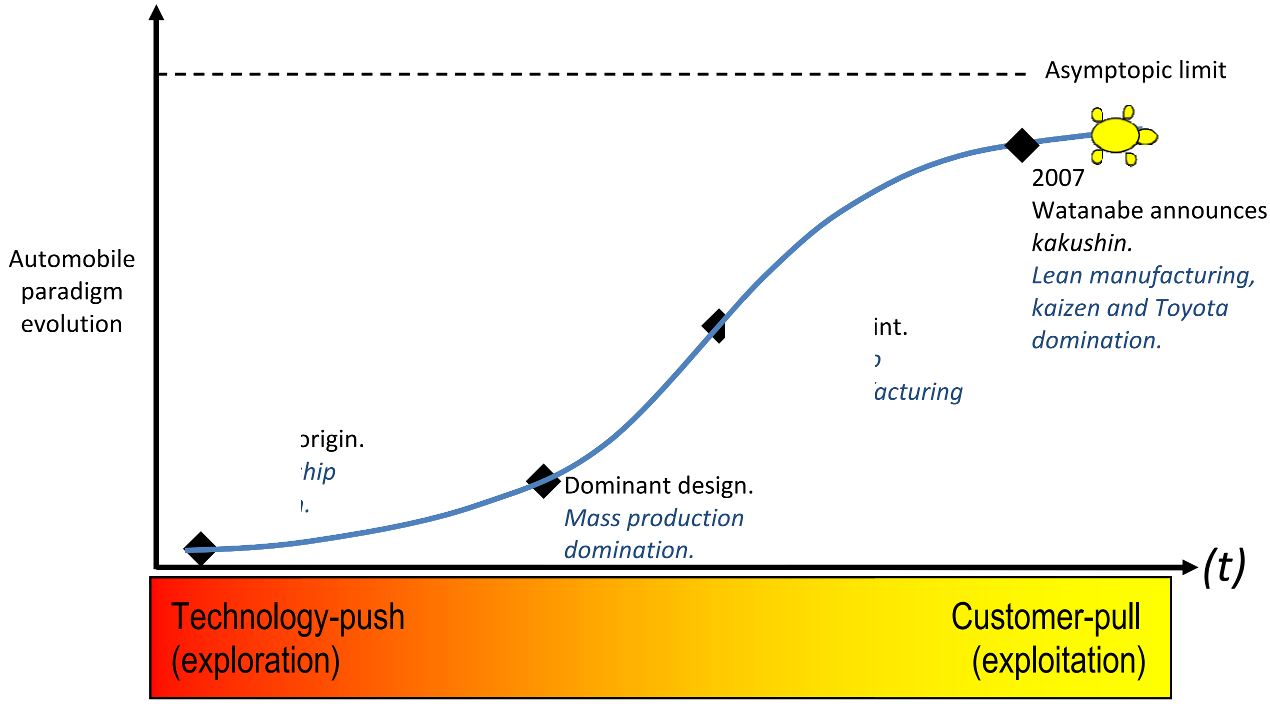
**Toyota and dominant design theory**

The candidate stated in Chapter 2 of this dissertation that the literature for Toyota innovation theory does not report dominant design theory. The candidate shows in Chapters 5 and 6 of this dissertation that the absence of dominant design theory in the cited literature can be explained as a reflection of Toyota’s historical contextual conditions. Here, the candidate shows that Toyota’s development of LM occurred after the entrenchment of the dominant design for the automobile paradigm. Furthermore, the candidate shows that the non-recognition and exclusion of dominant design theory in Toyota innovation theory does not affect adversely Toyota’s development of LM within the context of the exploitation of a mature technological paradigm.

### 4.5 DEVELOPED NEW PERSPECTIVE ON LEAN MANUFACTURING.

The candidate has developed their new perspective on LM and confirmed that LM represents the exploitative extreme of an explore-exploit continuum. Figure 7 summarises Toyota's position within the detailed analytical framework for this dissertation.

***Figure 7: Detailed analytical framework and Toyota's contemporary position within it. Source: Candidate's design.***




| | | | | | |
|---|---|---|---|---|---|
| Adopter type. | Innovators/ technology enthusiasts. | Early adopters/ visionaries. | Early majority/ pragmatists. | Late majority/ conservatives. | Laggards/ Sceptics and critics. |
| *Dominant design phase.* | *Formation.* | | *Emergence.* | *Development.* | |
| Producer time to market. | First mover. | Early follower. | Late entrant. | | |
| Market development. | Early. | | Mainstream with network externalities. | | |
| **KEY TECHNOLOGICAL ERAS** | | | | | |
| Utterback and Abernathy (1975). | Uncoordinated process. | | Systemic process. | | |
| Dosi (1982). | Paradigm emergence. | | Paradigm maturity. | | |
| Anderson and Tushman (1990). | Ferment. | | Incremental change. | | |
| Steele (1997). | Product innovation and engineering domination. | Process improvement and manufacturing domination. | | Capital intensity and finance domination. | |

## 4.6 SUMMARY.

This chapter detailed established theory and developed the candidate's new perspective on lean manufacturing that was outlined in Chapter 3 of this dissertation. The candidate showed that the relationship between lean manufacturing and its predecessors can be evaluated through six dimensions of innovation, which encompass the established theory for lean manufacturing, innovation management, behavioural science and economics. The six dimensions of innovation are: (1) Object of change, (2) Degree and frequency of change, (3) Relative time to market, (4) Technological trajectories, (5) Cost dynamics and (6) Relationship to the dominant design.

The candidate submits that the development of their new perspective on lean manufacturing in this chapter achieved substantially the outcome that was planned in the strategic argument mapped in Table 3 of this dissertation. There are two key parts to the outcome, which can be summarised as follows. Firstly, the theory contains three dominant manufacturing paradigms that evolved in a **systematic** manner in which lean manufacturing is **equal** to the other two paradigms. Secondly, lean manufacturing was confirmed to be the exploitative extreme of an explore-exploit continuum for the three paradigms.

# CHAPTER 5
# CRAFTSMANSHIP, MASS PRODUCTION AND LEAN MANUFACTURING.

## 5.1 INTRODUCTION.

The practices of lean manufacturing are inserted into the theory that was developed in Chapter 4 of this dissertation and are evaluated against the theory in this chapter, according to the strategy in Table 3 of this dissertation. Precipitative events in the automobile's technological trajectory are confirmed, which include the automobile's disruptive origin, dominant design, inflexion point and eras of domination by lean manufacturing's predecessors. The key attributes of lean manufacturing and its predecessors are determined and their competitive advantages are established.

## 5.2 THE AUTOMOBILE PARADIGM.

The first internal combustion engine is regarded to have been built in the 1600's by the English inventor Moreland, who used gunpowder to drive crude water pumps. However, it was not until 1879 that Karl Benz[35] created the first reciprocating piston engine that would power the first functional automobiles (Quintessence, 2009, p. 234).

### 5.2.1 Disruptive origin.

This dissertation regards the automobile's disruptive origin to be in 1886 when Benz lodged a patent[36] for what is regarded to be the first practical petrol engine automobile (Quintessence, 2009, p. 446).

### 5.2.2 Dominant design.

Dominant design theory is rooted in analysis of the U.S.A. automotive industry and is now accepted as standard perspective (Windrum and Birchenhall, 1998, pp. 110-111). The automobile industry is regarded as "the quintessential example" of dominant design mechanics (Teece, 2007, p. 1326). The automobile's dominant design is considered to have emerged in 1923, in that it embodies a standardisation of high-order and core concepts of which most are recognisable today (Suarez and Utterback, 1995, p. 417). Key features include an all-steel closed body[37] (Suarez and Utterback, 1995, p. 417), resolution of the struggle[38] between electric, steam and petrol engines (Teece, 2007, p.

[35] Benz based his design on Otto, who patented the 4-stroke cycle in 1877 (Quintessence, 2009, p. 400).

[36] The coversheet for Benz's "horseless carriage" patent is shown in Appendix B of this dissertation.

[37] Ohno (1988, pp. 103-104) described the 1920s as significant growth period with the arrival of the "sedan type body", which typified the shift from timber and cloth frames to all-steel. A "tendency towards the permanent top" was identified as a trend in automobile development in 1922 (Digest Books Inc., 1971, p. 191). When Lord Cottenham was asked by the London Daily Express in 1930 to prophesise what he would envision in the 1940 London Motor Show, he stated: "There is none with a fabric body. All are steel. And I can not see a single open one" (Automobile Year, 1982, p. 84). Lord Cottenham was a successful and popular racing driver in the mid 1920s. He wrote numerous non-fiction books on motoring and later served on the Roads and Road Transport Committee to the House of Lords and advisor to the Metropolitan Police Driving School (U.K.) (Advanced Motorists Worcestershire, 2010).

[38] Electric and steam powered automobiles were more reliable than petrol powered automobiles before 1900 (Clark, 1985, p. 243). The first practical electric automobile was roadworthy in 1842 (an earlier prototype was constructed in 1832) and *circa* 1900 electric power was an equal contender with steam and petrol. Electric taxis dominated many large U.S.A. cities in this era because they were clean and quiet (Quintessence, 2009, p. 322). The steam advocate's perspective is captured by Fletcher (1904 cited in Arthur, 2004, p. 368): "Every steam carriage which passes along the street justifies the confidence placed in it; and unless the objectionable feature of

1326), fixed architecture such as steering wheel instead of tiller (Clark, 1985, p. 240) and 4 wheels via a transmission and drive train connected to a frame rather than axles (Henderson and Clark, 1990, p. 14), *etc.*

Symbolically, the automobile paradigm's dominant design is associated with the Model T Ford (Martin, 1983, p. 223).

### 5.2.3 Inflexion point.

The candidate believes that Feigenbaum (1956, p. 93) made a prophetic observation in 1956: "the electrical relay that could command the lion's share of the 1950 industrial market is no longer acceptable for the 1956 operating needs. Consumers are progressively more minute in their examination of the finish in appliances, or in the judgement of the tone of the radio or television set". Feigenbaum's historical timing is significant. MP is the dominant manufacturing paradigm in 1956 U.S.A. and because of its success has proliferated globally. Feigenbaum is a production engineer with General Electric Company at this time and faces the challenge of simultaneously increasing quality and lowering cost (Australian Quality Council, 1994a, P. 3-17).

The candidate contends that Feigenbaum's 1956 manufacturing challenges and proposed solution can be regarded as a metaphor for the automotive industry of that time.

**TQC, customer satisfaction and waste.**

Feigenbaum (1956, p. 94) professes a solution to his manufacturing challenges: "Fortunately, there is a way out of the dilemma imposed on businessmen by increasingly demanding customers and by ever-spiraling costs of quality. This "way out" seems to lie in a new kind of quality control, which might be called "total quality control." The underlying principle of this total quality view — and its basic difference from all other concepts — is that, to provide genuine effectiveness, control must start with the design of the product and end only when the product has been placed in the hands of a customer who remains satisfied". Here, the candidate argues that Feigenbaum sensed a fundamental shift in competitive terms that embraces customer-pull and systemic waste elimination at its heart.

Feigenbaum's concept of a **hidden plant** is significant to this dissertation. Feigenbaum argued that ineffective producers have a hidden plant, which manufactures waste and excess capacity. Feigenbaum presented evidence that waste and excess capacity can be as high as 40% (Feigenbaum,

the petrol carriage can be removed (noise and pollution), it is bound to be driven from the road, to give place to its less objectionable rival, the steam-driven vehicle of the day". The tripartite power struggle is reflected in the 1902 New York Automobile Show, which had 139 exhibits: 58 steam, 58 petrol, 23 electric (Digest Books Inc., 1971, p. 25).

1983 cited in Australian Quality Council, 1994a, p. 3-18; Feigenbaum, 1991 cited in Bicheno, 1994, p. 12).

Feigenbaum's hidden plant is significant to this dissertation for three reasons. Firstly, the hidden plant represents MP. Secondly, the candidate expects to show that the hidden plant has a direct relationship to LM. Thirdly, the candidate asserts and expects to show that the hidden plant is hidden for a functional purpose.

**Ford and automotive mass production in 1955 U.S.A.**

Feigenbaum's statements coincide the greatest disparity in production between Ford and Toyota. Ford builds more that 8,000 vehicles[39] daily in 1955 whilst Toyota builds 23,000 annually (less than 3 days Ford production) (Holweg, 2006, p. 434). Ford amassed 76% share of the global automobile market by 1950 and is the greatest automotive manufacturer in the world (Davis, 2006, p. 130). Ford reaches its peak of domestic sales in 1955, holding 25% share of the U.S.A. automobile market (Holweg, 2007, p. 423).

1955 is significant for U.S.A. automotive producers generally for three reasons. Firstly, 1955 is when U.S.A. automotive producers achieve their historical peak of holding 95% of the domestic automobile market share (Mika, 2006, p. 5). Secondly, imports from Japanese producers are absent (Holweg, 2007, p. 423). Thirdly, 1955 marks a shift to stagnation[40] in productivity (Cusumano, 1988, p. 35). Womack *et al*. (1991, pp. 43-44) regard 1955 as signifying the peak of automotive MP in U.S.A. and the transition point to LM.

1955 is important to this dissertation because it represents Ford's mass production peak. The candidate will show that Ford epitomises automotive mass production.

**Toyota in 1955.**

Ohno (1988, p. 111) highlighted that 1955 marked a dramatic shift from low to high economic growth in Japan generally and for Toyota specifically. The change in economic conditions can be attributed to Japanese Governmental Policy and strategic decisions by Toyota. The Japanese Government enacted the Automobile Manufacturing Business Law in 1936, which protected and assisted domestic Japanese automotive producers. The Automobile Manufacturing Business Law suppressed effectively foreign producers, by requiring foreign producers of more than 3000 vehicles annually to apply for a licence. A further condition was that more than 50% of the foreign producer's directors and

[39] Vehicle includes automobiles and trucks.

[40] Paradoxically, the stagnation would be arrested by the migration from MP to LM (Womack *et al*., 1991), whereby "the student (Toyota) had traded places with the teacher (Ford)" (Toyota Motor Corporation, 1987, p. 130).

shareholders must be Japanese citizens (Editor, 1988 cited in Ohno, 1988, p. 132). The 1936 Automobile Manufacturing Business Law lasted until 1945, when it was superseded by another Governmental Policy in 1953[41]. The new policy limited foreign imports to 1% of the Japanese market (Cusumano, 1988, p. 31). The Japanese Governmental Policies reflected the influence of U.S.A. in Japan. Japan controlled fully its policies before World War 2 but came under direct influence from U.S.A. from 1945. Here, a grave fear gripped Toyota that the Japanese market would be liberalised and opened fully to foreign investment[42] (Toyota Motor Corporation, 1987, pp. 128-130). Ohno (1988, pp. 85-86) explains that from 1945, Toyota's founder Kiichiro Toyoda realised that to be a competitive global entity in its own right, Toyota must develop and rely upon its capabilities. Toyoda has a vision of competing through cost and quality (Toyoda, n.d. cited in Ohno, 1988, p. 84). Accordingly, from 1945 Toyota installed progressively an intensified cost, quality and operations focussed mindset (Ohno, 1988, p. 33).

Toyoda's vision began to show its potential by 1955. The entire Japanese vehicle production in 1950 consisted of 31,597 automobiles and trucks, which were shared between Toyota, Nissan, Isuzu and Hino (equivalent to 1 day of U.S.A. production) (Cusumano, 1988, p. 31). Toyota surged ahead of its domestic rivals: by 1955 Toyota dominated Japanese automotive production and by the late 1950's Toyota had ventured[43] into the U.S.A. market (Cole and Flynn, 2009, p. 69). A symbol of Toyota's intent was the unveiling of its first global automobile in 1955, called the Toyota Crown (Toyota Motor Corporation, 1987, p. 119). Toyota's manufacturing systems and Japan's economic conditions provided a platform upon which Toyota enjoyed a period of stable and sustained growth. Toyota's former president Eiji Toyoda explained this in 1987: "For more than 30 years now, Japan has been almost too free of turmoil. Such a long period of almost unbroken tranquillity may be unusual in recent history. But there is no denying that this has been most fortunate for Toyota. The trade friction between Japan and the U.S. following the second oil shock[44] is probably as close as we have come to a crisis" (Toyota Motor Corporation, 1987, pp. 166-167).

Toyota's sustained growth had significant outcomes for the U.S.A. automotive industry. Ford's global market share fell from its 1955 record of 76% to 30% by 1980 (Davis, 2006, p. 130). Moreover, 26.7%

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[41] This policy lasted until 1975 (Cusumano, 1988, p. 31).

[42] Toyota feared particularly the U.S.A. MP giants. Toyota initiated talks with Ford in 1961 of a possible business association. The talks failed but were revitalised in 1980 (Toyota Motor Corporation, 1987, pp. 128-130).

[43] Toyota withdrew in 1961 because of poor quality and weak sales (Cole and Flynn, 2009, p. 69).

[44] The 1970's had two global oil supply crises arising from middle-east conflicts and OPEC output restriction. There was a general period of global high inflation and unemployment with manufacturing over capacity (Ortt and van der Duin, 2008, p. 526). Oil prices soared, quadrupling between 1973 and 1974 (Baumol and Blinder, 2005, p. 218) with a corresponding focus on fuel efficient automobiles (Cole and Flynn, 2009, p. 70). The first oil shock hit Toyota in October 1973 and the second in 1975 (Toyota Motor Corporation, 1987, pp. 145-146). The Japanese economy collapsed to zero growth (Ohno, 1988, p. 1), resulting in Toyota reducing production in 1974 for the first time since successive increases from the 1930's (Ohno, 1988, p. 113). Toyota's ability to deal with the oil crises drew attention to its manufacturing system (Ohno, 1988, p. 113; Lewis, 2000, p. 960).

of U.S.A. automobile sales in 1980 were imported with 22.2% coming from Japan. Japanese imports into U.S.A. continued to rise to approximately 40% by 2005 (Holweg, 2007, p. 423).

1955 can be regarded as the inflexion point in the technological trajectory for the automobile paradigm.

**The Toyota shop floor in 1955.**

Toyoda's vision propels the development of Toyota's manufacturing system, which is centred generally on 1955. Monden (1994, p. 13) explains the rationale for the development of LM: "Toyota thought consistently, from about 1950, that it would be dangerous to blindly imitate the Ford (MP) system". Whilst Toyota used MP generally before 1945, Toyoda's vision instigated the complete reorganisation of Toyota's manufacturing system. Toyota focussed on the development of an efficient manufacturing system after 1945, which was based on the philosophy of "innovation in production management" (Cusumano, 1988, p. 30). The new system was developed and implemented through the 1950s and 1960s (Cusumano, 1988, p. 30). The contemporary LM author Mika (2006, p. 5) reports: "The decade of the 1950s was a time of transition for manufacturing (at Toyota)". The development of Toyota's new manufacturing system correlated to an expansion in product volumes and variants, which created new challenges to overcome. Toyoda (cited in Toyota Motor Corporation, 1987, p. 123) explains: "Up until 1955, sales of Toyota vehicles were all handled by a single Toyota dealer network. But as the number of our models increased, this setup grew more and more inadequate". Ohno (1988, p. 33) determines that the solution for an efficient manufacturing system that can accommodate multiple product variants is the implementation of production **flow** as the default condition. According to Ohno (1988, p. 33): "After 1955, however, the question became how to make the exact quantity needed".

The development of Toyota's manufacturing system in 1955 resulted in five key outcomes. The key outcomes described in the following section can be regarded as the foundations of LM and are expounded in Section 5.5.3 Lean manufacturing era in this dissertation. The first outcome was that 1955 marked the midway point between the pilot and group implementation of *kanban* (Monden, 1994, p. 37). Secondly, Ohno introduced considerable synchronisation between processes and small lot size component mixing for mixed model production runs (Cusumano, 1988, p. 35). Thirdly, Shigeo Shingo began lecturing Toyota on the "Separation between man and machines" (Mika, 2006, p. 5). Fourthly, Ohno began the shift from automation to autonomation in manufacturing (Ohno, 1988) and implemented the first *andon* (line stopping) devices (Cusumano, 1988, p. 35). Fifthly, Shigeo Shingo was charged with the development of the Single Minute Exchange of Die (SMED) system (Shingo, 1983 cited in Holweg, 2007, p. 422). The five key outcomes from 1955 had an immediate impact on Toyota's manufacturing efficiency. The vehicles manufactured per worker per year tripled between 1955 and 1957 and increased a further 60% by 1964 (Cusumano, 1988, p. 34).

The timing for the development of the foundation of Toyota's (lean) manufacturing system is consistent with a 1955 inflexion point in the technological trajectory for the automobile paradigm.

**5.3 DOMINANT MANUFACTURING PARADIGMS.**

Technological and demand discontinuities provide opportunity for the reorganisation of production (Jacobides *et al*., 2006, p. 1205). Similarly, environmental changes in an industry provoke adaptive responses from its producers, which require an appropriate manufacturing paradigm to effect operational effectiveness (Spina *et al*., 1996; Siggelkow and Levinthal, 2003; Das and Joshi, 2007, pp. 644-645). Whilst the horseless carriage ushered in a technological discontinuity, it would not remove horses from the streets without mass adoption. Mass producers introduced the automobile to the masses through reorganised production and created a demand discontinuity, which resulted in the obliteration of CR producers who are unable to adapt. Yet, from the consumers' perspective, what a technology is and how it meets their needs "is not defined in one fell swoop" (Clark, 1985, p. 245). Toyota realise that MP suits rapid growth (Imai, 1986, p. 24) but does not address the technological discontinuities of the post-Model T Ford era, which arose from increased complexity in consumer expectations (Ohno, 1988, pp. 104-105). Here, the candidate argues that Toyota recognised successfully the appropriate contextual focus of innovation within the automobile paradigm (Clark, 1985; Dosi, 1988; Roberts, 2007, p. 51) and the potential of the value within its supply chain (Christensen and Rosenbloom, 1995, p. 255). Consequently, the automotive industry saw another production reorganisation to LM, which is adapted to slow growth and increasing competition through productivity and product options (Ohno, 1988, p. 66).

The candidate notes that their contention for the evolution of LM from MP and CR has parallels with Mintzberg's (1983, Chapter 1) evolution of manufacturing systems. Mintzberg argued that the organisation and reorganisation of manufacturing systems follows a predetermined order according to their contextual conditions. Here, the candidate accords with Mintzberg in three respects. Firstly, CR can be characterised as a system of mutual adjustment, whereby coordination is achieved by informal communication. Secondly, escalating production volumes require coordination through direct supervision and the standardisation of processes and outputs, which the candidate argues accords with MP. Thirdly, the increased complexity from advanced process synchronisation that arises from efficiency initiatives requires the cross-standardisation of worker skills in addition to standardised processes and outputs. According to Mintzberg, this represents a partial return to CR and autonomous coordination. Here, the candidate argues that Mintzberg's final production organisation represents LM.

The candidate asserts and expects to show that CR, MP and LM follow an ordered pattern of antecedents.

### 5.3.1 Craftsmanship era.

The 1900 automotive industry had more than 1000 different automobile producers. The composition was estimated to be 600 in France, 110 in Great Britain, 80 in Germany, 60 in U.S.A., 55 in Belgium, 25 in Switzerland, over 20 in Italy and many scattered elsewhere. Total global automobile production was estimated at "several thousand" (Automobile Year, 1982, p. 10). Automobile production was dominated by Europe in 1900 but spread rapidly to U.S.A.. The number of different automobile producers in the U.S.A. since the automobile's inception is not known, but is estimated to be between 2000 and 3000 (Digest Books Inc., 1971, p. 10). The overwhelming majority of automobile producers existed during the automobile's disruptive origins and are now extinct.

If a global production of "several thousand" is defined as 2000, then the average annual 1900 automobile production per producer was approximately two units. Here, it can be said that the automobile's disruptive origin was dominated by CR manufacturing, which is characterised by small workshops of highly skilled workers who make products to customised specifications. The primary competitive advantages of CR are flexibility, manufacturing universality and organic processes (*e.g.* Hayes and Wheelwright, 1979, p. 137; Brown 1996, p.145). CR's key attributes are summarised in Table 18.

**Craftsmanship and dominant design formation.**

CR can be said to reflect the exogenous economic conditions in the first era of the automobile's technological trajectory. The automobile's installed base is minor and the industry comprises first-mover producers who manufacture for innovator and early adopters. The typical CR consumer is captured by Automobile Year (1982, p. 10) as being "might-be aristocrats obsessed with novelty, sportsmen intoxicated by speed or even doctors and industrialists whose lives were enlivened and made easier by the automobile". CR consumers are adventurous and novelty seeking. Moreover, CR consumers have typically substantial financial resources and can afford losses from unsuccessful adoption. Yet, by adopting the automobile CR consumers played a vital role in the automobile's diffusion, by introducing it to the mainstream social system (Schilling, 2005, p. 46). Whilst there are the kernels of a potential mainstream market, the automobile's dominant design is yet to emerge. Potential consumers are confronted with unfamiliar possibilities because the concepts for understanding and evaluating the automobile are unformed (Clark, 1985, p. 245). *E.g.* Benz's 1886 patent differs from the automobile's contemporary dominant design by being 3 wheeled and tiller steered with a 1 cylinder engine and hand throttle (Quintessence, 2009, p. 446). Purchase decisions are framed typically within the rudimentary choice between a "horseless carriage" and "carriage with a horse" (Clark, 1985, p. 245). The CR era was characterised by experimentation from both the producers' and consumers' perspectives, which resulted in fragmented and often incommensurate automotive technologies. Producers and consumers interacted heavily in product innovation, which introduced great variation in product architecture, features and performance dimensions (Suarez and Utterback, 1995, pp. 418-419). Moreover, CR consumers did not enjoy the positive consumption benefits of the modern era because there were lacking and incoherent network externalities. *E.g.* the modern era enjoys complementary goods that extend the automobile paradigm through co-evolutionary lock-in (Burgelman, 2002, p. 342). The complementary goods of the automobile's modern era include standardised, abundant an disseminated petrol, generic spare parts and post-market accessories, dealerships and parts distributors, maintenance and cleaning services, motoring organisations, roadside assistance, academic institutions for formal automotive skills development and recognition, government research bodies[45], motor sports, financial products such as loans, leasing, used car trade-in[46] and insurance. Further, laws for automobile worthiness and traffic behaviour and beneficial public goods[47] such as permanent, sealed, maintained and expansive road networks with traffic control infrastructure.

The pre-dominant design CR era of the automobile's trajectory is consistent with the theory for the candidate's analytical framework.

Craftsmanship manufacturing is predisposed to design technology-push.

***Table 18: Key attributes of Craftsmanship.***
***Source: Candidate's design.***

| ATTRIBUTE | CRAFTSMANSHIP |
|---|---|
| Relationship to market. | **First-mover producers.**<br>**Innovator and early adopters.**<br>**Minor installed base with no mainstream market.**<br>**Lacking and incoherent network externalities.**<br><br>Great product diversity between competitors seeking market "redefinition" and expansion (Utterback and Abernathy, 1975, p. 641).<br><br>Marketing rather than manufacturing oriented. Likely to enter and exit market early (Hayes and Wheelwright, 1979).<br><br>Product and performance criteria not well defined.<br>Limited producer and consumer experience. Competitor actions largely unknown. Fundamental uncertainty with non-trivial technological diversity vying for customer acceptance.<br>Customer learning and conceptions unformed (Clark, 1985). |

45 *E.g.* AutoCRC in Australia.

46 Ohno (1988, pp. 103-104) attributed partially automobile proliferation to the advent of used car trade-ins, improved roads and instalment payment plans.

47 Beneficial public goods are valuable socially and government provided generally (Baumol and Blinder, 2005, p. 237).

| | |
|---|---|
| | Products sold at very high prices (Krafcik, 1988, p. 42).<br><br>Perceived value founded on hedonic consumer needs (Franke *et al*., 2009).<br><br>Battle for acceptance as industry standard in emerging market (Soh, 2010, p. 438). |
| Relationship to product development cycle. | **Dominant design formation.**<br>**Competency destruction.**<br><br>Early in product (and process) life. Rapid development and frequent changes (Utterback and Abernathy, 1975, p. 641).<br><br>First phase in product life cycle (Hayes and Wheelwright, 1979, p. 137).<br><br>Early fluid state, pre-dominant design. Focus on core concepts at architectural level (Clark, 1985).<br><br>Prototype phase (Brown, 1996, p.139). |
| Competitive advantages. | Flexibility and ability to cope with uniqueness in products. Relatively low capital intensity. Suits new product development. (Hayes and Wheelwright, 1979).<br><br>Rapid and fundamental product innovation (Clark, 1985, p. 235).<br><br>Built-in flexibility and redundancy. Less need for preventative and integrated maintenance with fewer consequences for stoppage and environmental risk (Jonsson, 2000, p. 708).<br><br>Rapid response to changing product specifications (Boyer and Lewis, 2002, p. 11). |
| Process characteristics. | Uncoordinated, largely manual and unstandardised operations based on general purpose machinery. Fluid, loose and unsettled relationships between process elements. Inefficient (Utterback and Abernathy, 1975, p. 641).<br><br>Unstable, fluid, flexible, unspecialised, general purpose machines, skilled workers, labour intensive with erratic work flow. Infrequent process innovation. Low cost focus (Clark, 1985).<br><br>Fluid, non cost-effective, long lead time, jumbled flow with high worker skills (Hayes and Wheelwright, 1979).<br><br>Master craftsman with high span of control (Krafcik, 1988, p. 42).<br><br>Optimal system for high product variety with low volume production (Tombak, 1990, p. 226).<br><br>Process oriented layout based on machine function or fixed around product. Automation forgone for general purpose. Dynamic material handling. Scheduling often driven by capacity or competitive priorities (Brown, 1996, pp.136-141).<br><br>Flexibility priority over cost (Boyer and Lewis, 2002, p. 11). |

### 5.3.2 Mass production era.

Ford's Model T and its manufacturing systems contributed significantly to the emergence of the automobile paradigm's dominant design. Ford heralded a period of great stability for early mainstream adopters in their conceptualisation of the new technological paradigm. The Model T represented an excellent fit between product design and consumer requirements and was received with generous market ratification. The stabilisation of product concepts facilitated the crystallisation of manufacturing systems and created a framework for future consumer learning and technical development in product and processes (Clark, 1985, p. 246).

**Interchangeable parts.**

The great innovation of MP is regarded to be the consistent interchangeability between parts and the facilitation of their easy attachment (Womack *et al*., 1991, p. 27). Standardisation as a MP strategic strength is embedded in CR's fundamental weakness of being unable to produce consistently. Standardisation is the key enabler that allowed Henry Ford to fulfil his vision of building a car for the "great multitude[48]", such that "it will be low in price so that no man making a good salary will be unable to own one" (Ford, n.d. cited in Smith, 2009, p. 50). Ford realised that if efficiently mass produced, standardised and gauged parts would reduce dramatically product cost through economies of scale[49] (Hayes and Wheelwright, 1979, p. 137). Moreover, the resultant mass adoption would provide a massive market lead in installed base with the benefit of market leader status leadership and also precurse the development of positive consumption externalities. The tremendous capital intensity in plant establishment stood to be an appreciable asset, which would allow Ford to reap early operating profits and grow in value as competition increased through imitation (Jacobides *et al*., 2003, p. 1217). Here, the opportunity cost in capital investment was financially handsome because it provided an efficient conversion cost and barriers to entry for other producers from supply side factors, which placed Ford is powerful strategic position (Dosi, 1982, pp. 158-160). Ford realised that product rationalisation was required in addition to component and process standardisation in order to effect maximum leverage through economies of scale. Ford reduced its product range to one[50] product, which was the Model T (Ford, 1926, p. 81). Here, Ford (n.d. cited in Management Today, 2005, p. 19) boasted: "People can have the Model T in any color, so long as it's black". The emergence of the automobile's dominant design and the organisation of

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[48] Ford's vision for the great multitude was the genesis of the Model T. Vehicle ownership rose tenfold in U.S.A. between 1912 and 1921. The number of persons per car was 10.1 to 1 by 1922 (Digest Books Inc., 1971, p. 185). A later English equivalent was the Austin 7, which was intended to bring "motoring to the millions" (Seven ages of Britain, 2010).

[49] Economies of scale, or increasing returns to scale, means the producer achieves increasingly higher productivity in output as input is increased (Baumol and Blinder, 2005, p. 124).

[50] The Ford enterprise employed over 200,000 workers in 1926 but despite Ford's massiveness Henry Ford (Ford, 1926, p. 85) declared: "Our organization is not large enough to make two kinds of motor cars under the same roof". The Model T was the longest continuous production run of any automobile until being surpassed by the Volkswagen Beetle in 1972. The Beetle carries the same symbolism as the Model T: Volkswagen translates to people's car in English.

production to MP constituted a transformational redefinition of the automotive industry's productivity frontier (Porter 1996, p. 62).

**Standardisation and rationalisation as an enabler.**

Standardisation and rationalisation allowed Ford to organise its manufacturing system for the controlled utilisation of machinery and worker skills. Henry Ford (Ford, 1926, p. 85) reduced machine flexibility to "single purpose machinery" that is "called on to do only one operation". Henry Ford (Ford, 1926, p. 54) described this as "the machine concept of industry as opposed to the hand concept" which "takes for granted that a method can be discovered by which the entirety may be done by machinery and the man considered only as an attendant upon the machine". Here, Henry Ford contrasted directly the new ideology of MP with CR and provided continuity between them. An outcome for Ford workers was a condensation in their span of control through rigidly imposed work procedures[51] (Krafcik, 1988, p. 42). Here, Ford's objective was the achievement of mechanisation with less reliance of craft skills, such that any worker from one plant can perform the same operation in another (Ford, 1926, p. 85). Ford's systematisation and organisation of production is characterised by de-skilling, through the sub-division and fragmentisation of labour under bureaucratic management planning and control[52] (Wright, 1992). Here, organisational learning processes narrow competencies through specialisation and concentrated attention (Levinthal and March, 1993, p. 97). Henry Ford's MP ideology manifested ultimately in the concept of a conveyor belt, which according to Henry Ford (Ford, 1926, p. 103) is: "to take the work to the man and not the man to the work". The candidate defines the start of the automobile paradigm's MP era to be 1913, which was when the first moving assembly line (conveyor) is operational at Ford's Highland Park plant (Ford, 1926, p. xiii).

**Rapid growth and a mainstream market.**

The advent of the Model T is a precipitative event in the progress of the automobile paradigm along its trajectory for three reasons. Firstly, the need for standardisation and rationalisation required design consolidation and contributed greatly to the emergence of a dominant design. Ford believed that automobile technology has advanced sufficiently to enable the stabilisation of high-order and core concepts (Dorf and Byers, 2005, p. 82). Secondly, the Model T's rapid proliferation helped the automobile paradigm to cross its adoption chasm in the formation of a mainstream market, which signified a shift towards its commodification. 48% of the vehicles sold in U.S.A. in 1914 were a Model T (Smith, 2009, p. 50) and by 1919 Ford held 57% share of the global automotive market (Management Today, 2005, p. 19). The 5 millionth Model T was produced in 1921, 10 millionth in 1924 and 15 millionth in 1927. The Model T's price fell steadily, selling 40% less in 1926 than in 1914 (Ford, 1926). Ford's market surge was romanticised by Ohno (1988, p. 61) as: "the days when you

[51] Ford (1926, p. 87) describes a series of books called "Ford Tool Standards" used in training and maintaining work uniformity, which define standard practices "down to the last detail".

[52] Ford ideology (or "Fordism") is often tied to "Taylorism" and "scientific management" (Wright, 1992).

could sell everything you could make". The MP automobile was no longer confined to the exclusive reach of privileged novelty seekers and became accepted in Western lifestyles, which subsequently fueled growth in complementary externalities. The third reason why the advent of Model T is a precipitative event is that the massive sunk cost in capital investment for MP presented a formidable barrier for new entrant producers and CR producers attempting to compete on cost. Whilst CR would remain, it no longer dominated automotive manufacturing and was confined to niche market automobiles.

**Increased consumer expectations.**

Ford's MP paradigm was modified by its competitor in response to growing consumer expectations. GM president Sloan took advantage of Ford's emerging deficiencies of centralised control and a single model range. Sloan implemented two initiatives during the 1920s to 1930s, which would persist in automotive manufacturing. Sloan implemented firstly the concept of self-managing plants, which are characterised by the use of financial specialists and executive management by numerical performance indicators. Secondly, Sloan implemented a marketing department, which introduced a five model range in order to cater for an emerging spectrum of consumer expectations. A single model offering was no longer attractive to the maturing market and there was an increasing expectation of choice. Here, the concept of facelifts and options based on common platform was founded (Womack *et al*., 1991, pp. 41-43). GM had gained ascendency over Ford by the time Ford introduced its next model in 1927 (Management Today, 2005, p. 19). GM market share in the automotive industry rose from 10% to 45% between the early 1920s and 1940 (Sorenson, 2000, p. 577). Ford's rationalisation model had migrated from a position of strength to relative weakness because of increased consumer expectations. Ford failed to read the new market conditions before GM and lost the initiative over its rival.

**Pure "Fordism".**

Ford's manufacturing system and Sloan's marketing and management modifications are referred to as "recent Fordism" and prevailed in the U.S.A. automotive industry until 1980 (Krafic, 1988, p. 44). The candidate regards this hybrid to be a partial migration towards LM and defines MP as what is known as "pure Fordism" (Krafcik, 1988, p. 44; Ohno, 1988, p. 93; Sprague, 2007, p. 227). *I.e.* Ford's (1926) MP without Sloan's modifications. MP's key attributes are summarised in Table 19.

*Table 19: Key attributes of Mass Production.*
*Source: Candidate's design.*

| ATTRIBUTE | MASS PRODUCTION |
|---|---|
| Relationship to market. | **Early follower producers predominantly.**<br>**Rapid growth, crossing adoption chasm to early majority adopters.**<br>**Creation of mainstream market.**<br>**Significant installed base.**<br>**Emergence of coherent network externalities.**<br><br>Demand precursing through affordability, tending to cost optimising monopoly with stabilised supply and cost price (Ford, 1926, pp. 19-21).<br><br>Utility focussed product (Ford, 1926, p. 88).<br><br>Manufacturing oriented, seeking to mould market to its cost or process leadership (Hayes and Wheelwright, 1979, p. 138).<br><br>Appropriate for high growth market (Ohno, 1988, p. 109).<br><br>Non-dynamic (Arnold and Bernard, 1989, p. 411).<br><br>Limited options based on common platform (Womack *et al.*, 1991, p. 41).<br><br>Suited to market with low product variants (Monden, 1994, p. 9).<br><br>Effective in large, homogeneous market (Kotha, 1995, p. 24).<br><br>Emphasis on mass market (Hayes and Pisano, 1996, p. 25).<br><br>Focus on market stabilisation and dominance of market share (Ortt and Schoormans, 2004, p. 300) by crossing adoption chasm (Moore, 2004, p. 365). |
| Relationship to product development cycle. | **Dominant design emergence.**<br><br>Development through trial and error. Learning by necessity (Ford, 1926, Chapter 6).<br><br>Focus on stability in high-order and architectural product concepts (Clark, 1985).<br><br>Suited to long product development and life cycles (Kotha, 1995, p. 24). |
| Competitive advantages. | Interchangeable parts, allowing accurate and economical manufacturing (Ford, 1926, p. 83).<br><br>Barriers to entry from supply side factors (Dosi, 1982, pp. 158-160).<br><br>Growth synergy with network externalities (Katz and Shapiro, 1986, pp. 823-824).<br><br>High efficiency (Krafcik, 1988, p. 42). |

| | |
|---|---|
| | Economies of scale in manufacturing and distribution from long production runs (Arnold and Bernard, 1989, p. 411).<br><br>Stability and control in operations. Ability to produce consistent goods at prices affordable to majority (Kotha, 1995, p. 24).<br><br>Increasing returns to scale (Baumol and Blinder, 2005, p. 118). |
| Process characteristics. | Centralised operations with strong in-house capability. Focus on saving human labour through mechanisation. Centrally planned and standardised operations with work subdivided to single operations. Static workers and mobile inventory. 100% inspection by dedicated inspectors. High inventory (Ford, 1926, pp. 41-117).<br><br>"Command and control" management (Klein, 1989, p. 61).<br><br>Central planning approach with disseminated production schedules (push-system) (Monden, 1994, p. 5).<br><br>Single purpose machinery. Conversion from general purpose to single purpose by specialised and dedicated tooling (Ford, 1926, pp. 85-86).<br><br>Efficiency through "faster and more" (Ohno, 1988. p. 109).<br><br>Large lots of single parts produced. Inventory warehoused. Significant material handling (Ohno, 1988, p. 95).<br><br>Condensed span of worker control. Rationalised production (Krafcik, 1988, p. 42).<br><br>High degree of automation and dedicated tooling (Womack *et al*., 1991, p. 37).<br><br>Mechanistic, bureaucratic and hierarchical (Kotha, 1994, p. 24).<br><br>Buffering through inventory (Hopp and Spearman, 2004, p. 145).<br><br>Large scale production with change-overs minimised (Holweg, 2007, p. 422). |

### 5.3.3 Lean manufacturing era.

Toyota entered the mainstream automobile market as an insignificant late entrant producer, which had resolved to compete against the incumbent MP giants. The candidate believes that the great innovation of LM was its ability to compete against economies of scale, large sunk capital costs and product design capability. Toyota faced formidable barriers but held two late entrant advantages. Firstly, automobile design technology was available freely through reverse engineering, which allowed Toyota to decode the knowledge that was embodied in its competitors' products (Fosfuri and Tribo, 2008, p. 177). Here, Toyota could focus on Toyoda's vision of innovation in manufacturing systems for the achievement of low cost and high quality. Secondly, Toyota could take advantage of evolving consumer expectations, which were characterised by a growing upward revision in the consumer's quality and performance standards (Anderson and Salisbury, 2003, pp. 115-116; Frank and Enkawa, 2009, pp. 72-76). Here, Toyota had the opportunity to instigate a brand through the provision of exceptional utility for a familiar experience (Kim and Mauborgne, 2000, p. 130), which would re-establish the automotive paradigm based on new social norms (Bianchi and Miller, 1996, p. 195). Moreover, Toyota could create a new benchmark in the market through the value of an alternate approach and in doing so, redefine the concept of a producer's operational capabilities (Clark, 1985, p. 238). *I.e.* the delivery of low cost, tailored options with high quality and performance can become a market standard. The convergence of Toyota's intent and market receptivity provided a synergistic window (Dacko *et al*., 2008), which poised Toyota to create new capabilities with optimal relevance in market timing (Lee, 2008, p. 1276). Toyota's window of opportunity represented a positive dynamic interaction between consumer behaviour, producer behaviour and technological development (von Tunzelmann and Wang, 2007, pp. 207-209).

**Reduced operating budget.**

The achievement of low costs required the complete elimination of waste, low capital investment and reduced operating budget. Founder Kiichiro Toyoda realised that by producing the exact quantity of parts when required, or just-in-time (JIT[53]), large stocks of materials, parts and warehouses could be eliminated. Moreover, as former president Eiji Toyoda explained (Toyoda, cited in Toyota Motor Corporation, 1987, p. 57): "If, once this production system got underway, we were able to sell our finished product before payments were due on our materials and parts, we would no longer have any need for operating capital". Here, flow production was conceived, which was according to Ohno (Ohno, 1988, book title): "(a manufacturing system) beyond large scale production". Ohno observed that Ford's conveyors were an attempt to achieve a degree of flow. However, Ford's conveyors fought to keep pace because of the massive quantities of parts being delivered to them. Ohno (1988, p. 100) reasoned that Ford's high inventories created dams, which impeded workflow and forced the conveyors along. Ohno realised that the achievement of workflow meant that parts could not be pushed into production but must be pulled by production. Pulled-production in LM demands one piece flow, which in its pure expression means that only single parts are built when requested by their downstream process (Ortiz, 2006, p. 196). Whilst flow production could bypass theoretically[54] Ford's high inventories, flow created a challenge for inventory control. Ohno (1988, p. 5) realised that flow production required every link in the JIT chain to be connected and synchronised. Whilst Ford used conveyors for final assembly, it did not use them in upstream manufacturing (Sprague, 2007, p. 226). Ohno determined that in order to link assembly with manufacturing and keep capital expenditure low, Ford's physical conveyors must be replaced with invisible conveyors (Monden,

[53] Contemporary JIT is extended typically. *E.g.* right part, right quality, right moment, right quantity, right place (Schefenacker, 2007).

[54] The theoretical lean ideal is to produce one piece at a time. However, in complex environments this is difficult to achieve and can be regarded as an aspirational ideal. One piece flow implies a "bufferless (inventoryless)" state, whereas in practice lean can be described typically as a "best buffer" state.

1994, p. 12). Ohno drew inspiration from the emerging phenomenon of U.S.A. supermarkets. Ohno (1988, p. 26) explained: “From the supermarket we got the idea of viewing the earlier process in a production line as a kind of store. The later process (customer) goes to the earlier process (supermarket) to acquire the required parts (commodities) at the time and in the quantity needed. The earlier process immediately produces the quantity just taken (restocking the shelves). We hoped that this would help us approach our just in time goal”. The connection and synchronisation of processes in the Toyota manufacturing system context was facilitated through *kanban* (Japanese for tag[55]) (Ohno, 1988, p. 123). *Kanban* tags were attached physically[56] to parts and provided pickup, transfer and production information. Using the supermarket analogy, when a commodity is removed from a shelf a withdrawal *kanban* is sent to the purchasing department detailing the replenishment requirements. Similarly, if the manufacturing plant was nearby a corresponding production *kanban* would be sent, thereby pulling production at the customer’s behest. *Kanban* became a key feature of LM because it was a self-limiting inventory control, which also facilitated the synchronisation of the Toyota manufacturing system.

**Overproduction.**

*Kanban* addressed fundamentally the issue of excessive inventory, which was regarded by Ohno to be pure waste. Inventory elimination had multiple benefits, which included the elimination of the warehousing, transportation, handling *etc*. that excessive inventory required. Moreover, *kanban* contributed to improved quality in that it defined the necessary process and highlighted abnormal events when synchronisation failed. Ohno had achieved some synergy between waste elimination and quality improvement as self-reinforcing outcomes. A problem for Ohno was that whilst *kanban* limited inventory and assisted in defect prevention between processes, it did not eliminate completely overproduction or prevent defects from being created within the individual processes. Ohno (1988, p. 19) considered that the production capacity of Toyota’s manufacturing system was the sum of the work required and waste, such that “Present capacity = work + waste”. Here, Ohno had direct parallels with Feigenbaum’s concept of the hidden plant[57]. Feigenbaum (1956, pp. 99) reported that a great proportion of production capacity (in MP) was wasted in the production of scrap, quality inspection, bottlenecks, poor processing methods and lacking “spirit of quality-mindedness on the production shop floor”. A key point in Feigenbaum’s (1956) solution to the hidden plant was that the waste it produced must be eliminated by controlling the production of every individual process as an element within a total system. Similarly, Ohno reasoned that waste was overproduction fundamentally and that its elimination can be achieved by controlling the

[55] *Kanban* is sometimes referred to as card, label or signal (Takeda, 2006, p. 259).

[56] There are various forms of *kanban* depending on part type, lot size, contingency, physical layout *etc*. The most classical method is a card attached to a standardised parts bin (*e.g.* Waller, 2003, pp. 470-474).

[57] Feigenbaum expressed overproduction as: Actual capacity = Current operating capacity (known plant) + waste (hidden plant) (Bicheno, 1994, p. 12).

sources of waste. Here, the candidate argues that Ohno is in effect attempting to eliminate the hidden plant in Ford's MP system. Ohno observed two key aspects of overproduction that must be addressed in order to achieve flow. Firstly and similar to Feigenbaum, Ohno noted that scrap and quality inspection was a great source of waste in MP. Indeed, more than 3% of Ford's entire workforce in 1926 were dedicated quality inspectors (approximately 7000), which according to Henry Ford inspected "every part in every stage of its production" (Ford, 1926, p. 103). Ohno reasoned that the prevention of defects at their source would not only eliminate scrap but also the need for quality inspectors. The second key aspect of overproduction that Ohno observed was akin to Feigenbaum's (1956) waste of inappropriate processing methods. Here, Ohno believed that the synchronisation of processes and elimination of waste from overproduction must be founded on the concept of value-adding work. Ohno defined value-adding work as the absolute minimum of workers, machinery and information required to achieve just the right amount of product in just the right amount of time (Ohno, 1988, p. 57). Ohno's concept of value-adding work had two outcomes. Firstly, every process must be optimised. Secondly, producing too fast or slow is wasteful (Takeda, 2006, p. 108). Here, Ohno faced a further challenge. Ford used conveyor belts in assembly, which in part meted production flow. Ohno needed to devise a flow meter because Toyota would use conceptual conveyors. The elimination of waste from the aspects of defect prevention and process optimisation would result in two functional elements of LM, which act synergistically: Tact (time) and autonomation (Ohno, 1988, p. 4). Tact sets the rate of production flow. Autonomation prevent defects at the source, optimises processes and maintains Tact through the elimination of disruptive variation.

**Tact (time).**

A requirement of flow production is that the production rate of various products and their quantity manufactured must be coherent between processes. Here, variation is disruptive intrinsically because the uneven manufacture of product type and quantity between processes creates waste. *Kanban* must synchronise processes from two perspectives. Firstly, by providing the correct sequence of manufacturing processes. Secondly, by identifying the part that shall be manufactured, the quantity that shall be manufactured and its rate of manufacture. Here, Ohno was presented a significant challenge because the ultimate customer in the Toyota system of production flow was the external consumer. Ohno realised that he could control the internal operations at Toyota but not consumer demand. Ohno's (1988, p. 36) countermeasure to demand variation was to manage the synchronisation of flow such that "mountains should be low and valleys should be shallow". The principle behind Ohno's countermeasure was production levelling[58], which strove to produce the same amount of products every period in order to minimise the effects of demand variation

[58] Production levelling is also known as production smoothing (depending on the timeframe used) (*e.g.* Monden, 1994, p. 63) or *heijunka* (Hines *et al.*, 2004, p. 1000).

(Monden, 1994, p. 63). Production levelling averaged the quantity produced of each product type over a given period and in doing so provided a degree of predictability. The predictability afforded by production levelling allowed Ohno to devise a mechanism for full synchronisation, which allowed the optimal sequencing of processes and labour allocation[59] that is coherent with consumer-pulled demand. Ohno's mechanism for full synchronisation was Tact[60] (total available cycle time), which provided a timeframe that allowed the regulation of manufacturing processes. Tact time is the ratio of the regular operating hours of a process to the quantity of parts required by the next process, which represents the time available to manufacture a part so that it matches customer-pulled demand. The timeframe provided by Tact allows the manipulation[61] of processes such that the closest effect to one piece flow is achieved according to an underlying flow rate (Ohno, 1988; Monden, 1994, Takeda 2006).

Process flow, synchronisation and Tact time redefined the MP concept of efficiency. Ohno contrasted MP with LM by comparing their approaches to cost reduction[62]. Here, Ohno observed that MP producers reduce cost by what Ohno called the "faster and more" approach, which represents economies of scale (Ohno, 1988, p. 109). LM producers in contrast, do not benefit by the faster and more approach if it is devoid of the continuity of production flow (Ohno, 1988, p. 63). According to Ohno (1988, p. 108): "Efficiency (in LM) is never a function of quantity and speed".

**Flexible workers and production facilities.**

An implication of Tact was the need for a flexible and multi-skilled workforce, which was supported by responsive production facilities. *E.g.* workers may be spread over more processes when Tact time is long because of low demand. LM workers required capability in the operation of multiple processes for multiple products, which is grounded within proficiency in the execution of LM's principles and objectives. Correspondingly, production facilities must allow flexibility in worker and part movement. Flexibility in production facilities was achieved through three key features. Firstly, the fixed purpose machinery and plant of MP was replaced with general purpose machinery and plant, which was re-configurable. Secondly, a Single Minute Exchange of Die (SMED) system was

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[59] LM workers are deployed to processes as required. If production capacity exceeds demand, then workers are deployed to unforced *kaizen* activities, other roles, other divisions or further training (Liker and Hoseus, 2008, pp. 344-349).

[60] Also known as *takt* (German for cycle) (Takeda, 2006, p. 140).

[61] The determination of optimal production levelling is beyond the scope of this dissertation suffice to say that the goal is to strive for one piece pulled flow (Takeda, 2006, p. 51). Similarly, for Tact in that it is a framework for determining optimal multi-process handling in the assignment of one man day per worker as a function of factors such as cycle time, worker capacity, facility processing ability, bottleneck processes *etc.* (Monden, 1994, Chapter 20). Cursorarily, Tact may be captured in an example: *E.g.* in one shift, 8 sedans and 4 coupes are required. Production levelling means the scheduling of 4 cycles of sedan-sedan-coupe, which totals 12 cars. If it was a 12 hour shift, the Tact time per car is 1 hour. Assuming 4 common wheels per car, then wheel Tact time is 15 minutes (4 per hour). If the normal wheel production rate is 6 per hour with 3 workers, then the cell can be reduced by 1 worker to give (nominal) 4 per hour with 2 workers.

[62] Ohno (1988, p. 62) related MP efficiency improvement to increasing production quantity, whilst in TPS it means reducing the number of workers. *E.g.* suppose a mass producer lowered cost through economies of scale but did not have corresponding sales, then overproduction in inventory and over-utilised worker deployment would result in waste (inefficiency). Efficiency in LM is improved by creating the required level of parts with fewer workers (and redeploying them effectively).

conceived, which facilitated[63] rapid tooling changeover. Thirdly, the static and isolated islands[64] in MP production were replaced with dynamic and integrated U shaped cells, which facilitated production flow, process synchronisation and modular capacity adjustment[65] (Monden, 1994, Chapter 11).

**Teamwork, empowerment and *kaizen*.**

The concept of flexibility through modular capacity adjustment is called *shojinka* in LM, which requires well trained and multi-functional workers that are adept at job rotation. *Shojinka* workers are empowered and encouraged to engage in *kaizen*, which is regarded in LM to increase morale and restore the dignity that was lost through the dehumanisation of MP. Here, *kaizen* accords with the Toyota pillar of respect for humanity (Monden, 1994, Chapters 11-12). *Kaizen* acts as an organisational learning mechanism that improves worker capabilities, promotes self-assurance and provides workers with the skills and confidence to deal with problems encountered in their domain (Levinthal and March, 1993, p. 104). Ohno (1988, p. 23) understood that for the achievement of flow production "teamwork is everything". Toyota workers are coached and mentored in LM principles and a collective process approach to problem solving at every opportunity in order to develop and maintain a strong *kaizen* culture (Liker and Hoseus, 2008, pp. 60-74; Osono *et al*, 2008, p. 33).

**Autonomation.**

Ohno strove to exploit directly the *kaizen* capability of his workers through autonomation[66], which is regarded as a state of synergy between machines and workers. The long production runs of MP and reliance on inspection meant that defects were not detected until after they were made, which often resulted in tremendous waste in materials and labour utilisation. Ohno (1988, pp. 7-8) reasoned that if a machine could stop automatically when the required quantity of components was manufactured, prevent the creation of defects at their source and stop if abnormal conditions were detected, then under normal conditions the machine would not require worker attendance. Workers could then supervise several machines simultaneously and improve productivity whilst defects were being prevented[67] automatically. Moreover, if a stoppage occurred because of abnormal conditions then respect for humanity and efficiency would improve through the enactment of *kaizen* problem solving (Monden, 1994, p. 225). Ohno's (1988, p. 6) solution was autonomation, which is "automation with a

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[63] SMED's innovation is the conversion of internal set-up (done when process stopped) to external set-up (done whilst process running) (Shingo, 1990, pp. 287-361).

[64] Production facilities that do not facilitate synchronisation are regarded to be isolated islands in LM (Monden, 1994, Chapter 11). This concept is expounded in Chapter 6 of this dissertation.

[65] Capacity adjustment as a primary buffering strategy against demand fluctuation in LM and is expounded in Chapter 6 of this dissertation. Toyota strive continually to generate excess capacity within existing production facilities based on the logic that if Toyota utilises existing machines and workers for excess capacity generation then the excess capacity generated costs nothing. Excess capacity allows buffering against increased production demand and the potential deployment of workers to unforced *kaizen* activities (Ohno, 1988, pp. 56-57).

[66] Also known as *jidoka* (Japanese for automation with a human mind) (Monden, 1994, p. 225).

[67] A key LM feature in automatic defect prevention is *poka yoke* (Japanese for mistake proofing). *Poka yoke* is expounded in Chapter 8 of this dissertation.

human touch". Autonomation installs intelligence into the machinery that enables it to detect and react to abnormal conditions (Ohno, 1988, p. 4). Autonomic machines are self-checking and when disturbances are detected they are self-stopping. Autonomation is founded on Shingo's work on the separation of man and machine, which separates manual from mechanical labour (Takeda, 2006, pp. 167-169). Here, *kaizen* and autonomation are self-reinforcing. Autonomic machines (mechanical labour) and a *kaizen* ready workforce (manual labour) constitute an autonomic nervous system, which behaves as an industrial reflex (Ohno, 1988, pp. 45-47). According to Ohno (1988, p. 7), stoppages from abnormal conditions "force awareness on everyone" and "when the problem is clearly understood, (*kaizen*) improvement is possible".

**Visual control and *andon*.**

Flow production and autonomation enable visual control, or management by sight, because disturbances are "forced to surface" by being visually obvious[68] (Ohno, 1988, p. 129). LM contrasts the large and dislocated production lots of MP where problems can be buried visually. Visual management allows abnormalities to be communicated clearly. Furthermore, when problems surface they become shared information and can be solved through collaborative effort (Liker and Hoseus, 2008, p. 311). However, Ohno realised that the development of autonomation capability requires learning and experience and in complex environments it is difficult to detect abnormalities through machinery alone. Here, Ohno extended the principle of autonomation through the concept of *andon*[69], which encouraged workers to use their judgement in what constituted abnormal conditions and empowered them to halt production at their discretion. According to Ohno (1988, p. 121), Toyota workers "should not be afraid to stop the line". The combination of autonomation (machine self-stopping) and *andon* (voluntary operator-stopping) facilitates fully *kaizen*, because problems must be resolved immediately in order to maintain production flow. The engagement of workers in the detection and solution of problems within their processes is a more humanistic approach than MP that creates a sense of ownership[70], which further motivates *kaizen* improvement (Monden, 1994, pp. 225-227). Moreover, continuous learning and experience accumulation leads to increased performance and reliability (Levinthal and March, 1993, p. 106).

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[68] The concept of visual management was extended to immaculate housekeeping through the 5S system of *seiro* (remove), *seito* (organise), *seiso* (clean), *seiketsu* (standardise) and *shitsuke* (respect rules) (Waller, 2003, pp. 447-458) or the English variant of sort, straighten, shine, standardise and sustain (Liker and Hoseus, 2008, p. 555). Occasionally a sixth S is added: *shukan* (habit) (Takeda, 2006, p. 257). The importance of housekeeping has some connection with Henry Ford, who argued for giving workers a "fancy polished tool" and "clean surroundings" in that "They make for the working spirit" (Ford, 1926, p. 201). Whilst Ford's theory does not relate directly to visual management, it did link work environment to performance and perhaps influenced the development of 5S.

[69] *Andon* is technically a visual operational status display that is colour coded, which in addition to indicating normal (green) and stopped (red) status also provides for a self-initiated operator call for help (yellow) (Ohno, 1988, p. 121; Monden, 1994, p. 232) *Andon* is often described and symbolised as a (pulled) cord (*e.g.* Stewart and Raman, 2007, p. 77; Mika, 2006, p. 151). *Andon* requires an environment of trust and fearlessness. "Pulling the *andon*" at Toyota may win praise (Liker and Hoseus, 2008, p. 7).

[70] LM production management roles changed dramatically from MP. Self-monitoring and feedback providing operations allowed managers to become problem solving facilitators and mentors (Klein, 1989, p. 61).

**Total Preventative Maintenance (TPM).**

The concept of TPM is associated strongly with LM (Shah and Ward, 2003, p. 129). Flow, defect prevention and autonomation caused Toyota to implement a rigorous *kaizen*-based preventative maintenance program, which strove to prevent disruption from machine breakdown and performance degradation (Ohno, 1988, pp. 101-102).

**Mass customisation capability.**

The ability to produce small lots that are based on actual demand with quick change-overs between products makes LM more responsive to diverse market demands than MP (Ohno, 1988, p. 39). Demand variability is a function of both product type and quantity produced, which stems from each product's distinct life-cycle. 1926 Ford was configured to manufacture a single product with a long life-cycle. The number of product options in 1955 multiplied and had much shorter life-cycles. The ability to cope with the demand variability created from multiple products with short life-cycles is a source of competitive advantage that could be exploited by LM's modular manufacturing system (Francas *et al*., 2009, p. 439). Conversely, if a great variety of products is not produced, having specific equipment and employing MP is more effective than LM (Monden, 1994, p. 9). LM forms a dichotomy with MP because of its capability to mass customise efficiently significant volumes a multiple products (Kotha, 1995, p. 22). Ohno's transformation of Toyota into a learning, *kaizen*-based organisation that effectively and rigorously implements improvements in process capability made Toyota successful in enhancing continually its mass customisation capability[71] (Huang *et al*., 2008, p. 725). The significance of this achievement is that not only did it enable LM to compete against MP, it allowed Toyota to retain a competitive advantage because mass customisation capability becomes increasingly a competitive advantage in maturing markets[72] (Francis and Bessant, 2005, p. 173; Pham *et al*., 2008, p. 695; Gosling and Naim, 2009, p. 741). The competitive advantage of mass customisation capability rests in the ability to deliver more perceived value to the customer through their co-design engagement in the customisation experience (Merle *et al*., 2008, pp. 40-43) and the achievement of a closer consumer preference fit[73] (Franke *et al*., 2009, p. 103).

**Reactive business strategy.**

The Toyota manufacturing system of flow production based on actual customer demand that facilitated mass customisation contributed significantly to the explanation of how LM was extended to become Toyota's all encompassing business model of customer-pull. LM behaves as a reactive

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[71] The candidate contends that mass customisation capability is not manufacturing flexibility *per se*. Whilst LM facilitates mass customisation relative to MP, both manufacturing systems are centred on a single, mature technological paradigm with significant production volumes. Flexibility and mass customisation capability in its truest form is found in CR, which is unbeholden to technological paradigms.

[72] Womack *et al*. (1991, p. 126) plotted the number of products offered against their volumes produced throughout the automobile's history. The results showed a clear trend to mass customisation.

[73] Mass customisation is often jargonised as the "post Model T Ford" modernity of "a market of one" (The genius of design, 2010).

mechanism that responds reflexively to customer signals in a stable market. The phase of the automobile's technological trajectory that is dominated by Toyota is characterised by automobile consumers having mature product knowledge and the ability to interact with the product development decisions of automobile producers (Clark, 1985, p. 244).

**Integrated supply chains.**

A logical outcome of Toyota's customer-pull manufacturing system was its projection to Toyota's supply base. Toyota is credited greatly for the contemporary practice of multi-tiered, highly integrated supply chains (Hines, 1996). Ford had tremendous in-house capability and self-sufficiency, which even saw investment in Ford's own rubber plantations and rail networks. If Ford could not achieve self-sufficiency, then Ford's suppliers were kept in check through a system of rigorous competitive bidding (Ford, 1926). Toyota in contrast, co-opted suppliers into an expanded co-operative enterprise[74], to a point where only 15 to 25% of value-adding occurs at Toyota proper (Hines, 1996, p. 6).

**Dominant strategic position.**

Ohno exploited the emerging weaknesses of MP in the same way that MP exploited the inherent weaknesses of CR. LM "technologically leapfrogged" MP in the same way MP leapfrogged CR (Schilling, 2003, pp. 29-30). Toyota's disruptive manufacturing paradigm set to render obsolete MP competencies, through a buffer in the relevance of knowledge and skills and a capability in ongoing competency enhancement (Lee, 2008). LM's intense integration and quality of worker interaction created a complex strategy, which raised a barrier to imitation. LM would remain resistive to replication for many decades, despite significant academic scrutiny and mimicry (Rivkin, 2000, pp. 824-825). Here, MP producers had three competitive disadvantages. Firstly, high sunk costs in capital equipment and worker competencies hindered the preparedness to embrace and adopt new approaches (Dacko *et al*., 2008, p. 446). Secondly, the task of internal and network reconfiguration was massive (Soh, 2010, p. 458). Thirdly, product and process transformation entailed a period of falling revenue, which required the promotion of an inferior product during which change could be managed (Liu and Ozer, 2009, p. 568).

**Reconfigured operations, mindset and dominant innovation strategy.**

Ohno (1988) had reconfigured completely MP in manufacturing systems design, mindset and dominant innovation strategy. Here, the candidate contends that LM transferred effectively a new set of innovation problems that arose from the normal maturation of the automobile paradigm into organisational architecture, such that *kaizen* is the solution. Table 20 summarises the key attributes of LM.

[74] Toyota supply chains are expounded in Chapter 8 of this dissertation.

*Table 20: Key attributes of Lean Manufacturing.*
*Source: Candidate's design.*

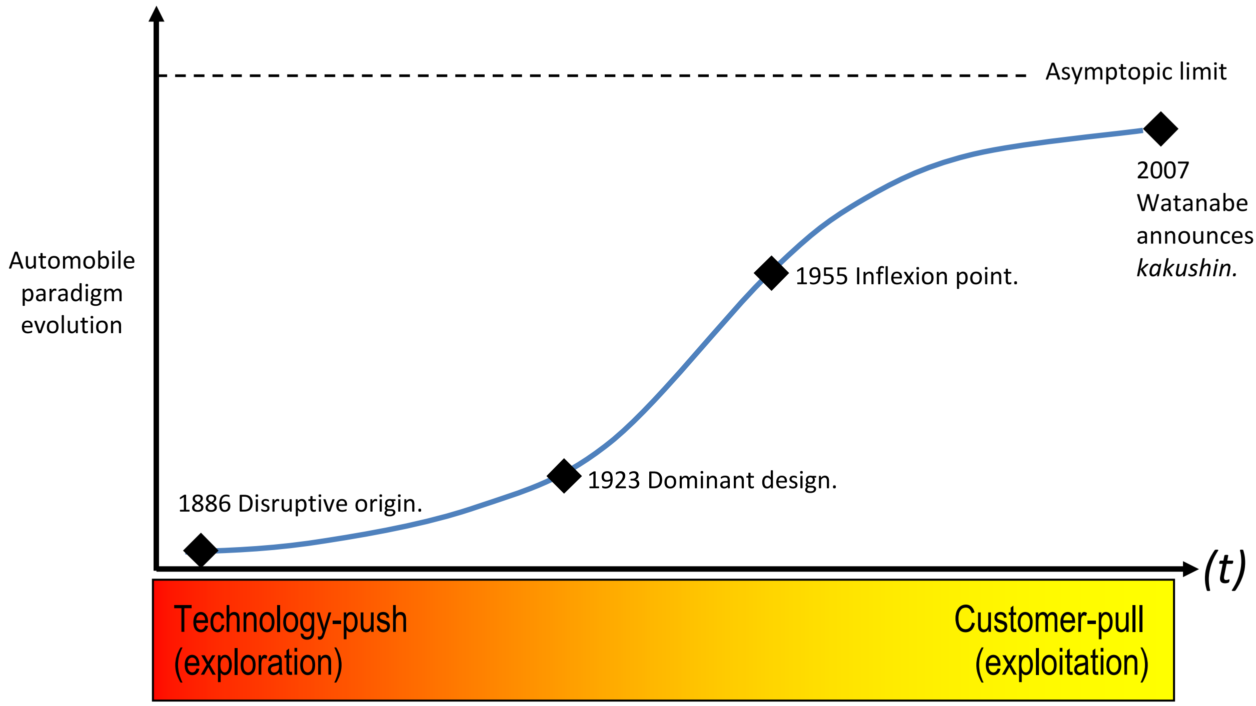
| STRATEGIC FEATURE | LEAN MANUFACTURING |
|---|---|
| Relationship to market. | **Late entrant and incumbent producers.**<br>**Mature, mainstream market.**<br>**Stable installed base.**<br>**Ecosystem of complementors.**<br><br>Suited to low growth market (Ohno, 1988, p. 97).<br><br>Production quantities based directly on actual demand (Ohno, 1988, p. 127).<br><br>Late market entrant with intent to compete through cost and quality (Toyoda n.d., cited in Ohno, 1988, pp. 85-86).<br><br>Production first focus (product second) (Ohno, 1988, pp. 20-21).<br><br>"Aggressive selling" of flagging models to keep production schedules level (Womack *et al*., 1991, p. 67).<br><br>New full car models rarely released. Focus on existing model variants, options and minor changes (Womack *et al*., 1991, p. 172; Monden, 1993, p. 102).<br><br>Sales policies to keep production schedule level (Liker, 2004, p. 125).<br><br>Perceived value founded on utilitarian consumer needs (Franke *et al*., 2009). |
| Relationship to product development cycle. | **Dominant design development.**<br>**Competency enhancement.**<br><br>Focus on process integration and enhancement of low-order product concepts (Clark, 1985).<br><br>Product release levelled according to fixed schedule for redesign, upgrade, freshen, facelift *etc*. (Liker, 2004, p. 123).<br><br>Strong reluctance to "reinvent the wheel". Consistent product development teams (Liker, 2004, p. 252).<br><br>Suited to acquiring and accumulating product knowledge in established market through reverse engineering and external supplier linkages (Fosfuri and Tribo, 2008).<br><br>Focus on institutionalising and improving proven best practice through competency enhancement (Osono *et al*., 2008, p. 84).<br><br>Concurrent data-based engineering with cross-functional teamwork and supplier input. Emphasis on manufacturability (Hines, 1996; Liker, 2004; Morgan and Liker, 2006). |
| Competitive advantages. | Inventoryless, warehouse-less with reduced operating budget (Toyoda, cited in Toyota Motor Corporation, 1987, p. 57). |

| | |
|---|---|
| | Lower capital investment than MP. Waste elimination and optimised production efficiency with high quality and consistent product performance (Toyota Motor Corporation, 1987; Ohno, 1988; Monden, 1994; Womack and Jones, 2005; Hines 2008).<br><br>Mass customisation capability and customer responsiveness (Ohno, 1988; Monden, 1994).<br><br>Skilled, motivated, engaged, empowered and trained continually workers. Ability to execute continuous improvement and competency enhancement (Imai, 1986; Ohno, 1988; Monden, 1994; Porter, 1996). |
| Process characteristics. | Level, JIT pull production based on customer demand (Ohno, 1988, p. 123-126).<br><br>Focus on increasing capacity within without increasing plant by reducing number of workers ("worker saving") (Ohno, 1988, p. 124).<br><br>Multi-process systems rather than multi-unit. Shift from single-skilled to multi-skilled. Turn worker movement into work (Ohno, 1988, p. 125).<br><br>Small lot sizes and quick setups (Ohno, 1988, p. 127).<br><br>Automatic and/or operator initiated line stopping when defects or abnormalities detected. Focus on preventing defects through fool-proofing devices (Ohno, 1988, p. 121-122).<br><br>Visual control and management by sight. Problems and abnormalities forced to surface. Waste recognition and elimination (Ohno, 1988, p. 129).<br><br>Abnormalities immediately and permanently eliminated by determination of genuine cause and implementation of countermeasures at source (Feigenbaum, 1956; Shingo, 1981; Deming 1986; Ohno, 1988, pp. 126-127).<br><br>General purpose machinery. Modular processes with rapid re-configuration (Shingo, 1981; Ohno, 1988; Monden, 1994).<br><br>Flexible workforce adept at job rotation (Monden, 1994, p. 5).<br><br>Buffering through excess capacity (Hopp and Spearman, 2004, p. 145).<br><br>Extensive supplier value-add. Large highly integrated and tiered supply chain with exclusive long-term contracts. High degree of trust, cooperation, knowledge sharing, technical embeddedness and bilateral design. Suppliers' extension of parent organisation, sharing risks and rewards in common fate. High investment in supplier development (Hines, 1996).<br><br>Efficiency through "continuity" (Ohno, 1988. p. 108). |

## 5.4 SUMMARY OF PRECIPITATIVE EVENTS AND MANUFACTURING ERAS.

Figure 8 summarises the precipitative events in the automobile's technological trajectory that were confirmed in this chapter.

***Figure 8: Precipitative events and manufacturing eras in the automobile's technological trajectory. Source: Candidate's design.***




| | | | | | |
|---|---|---|---|---|---|
| Dominant manufacturing paradigm | **CRAFTSMANSHIP** 1886-1913. | | **MASS PRODUCTION** 1913-1955. | **LEAN MANUFACTURING** 1955 to present. | |
| *Dominant design phase.* | *Formation.* | | *Emergence.* | *Development.* | |
| Adopter type. | Innovators/ technology enthusiasts. | Early adopters/ visionaries. | Early majority/ pragmatists. | Late majority/ Conservatives | Laggards/ Sceptics and critics. |
| Producer time to market. | First mover (**Benz**). | Early follower (**Ford**). | Late entrant (**Toyota**). | | |
| Market development. | Early. | | Mainstream with network externalities. | | |
| Technological era. | Product innovation and engineering domination. | Process improvement and manufacturing domination. | | Capital intensity and finance domination. | |

## 5.5 SUMMARY.

The practices of lean manufacturing were inserted into the theory that was developed in Chapter 4 of this dissertation and were evaluated against the theory in this chapter.

The candidate submits that their evaluation of lean manufacturing in this chapter achieved substantially the outcome that was planned in the strategic argument mapped in Table 3 of this dissertation. There are four key parts to the outcome, which can be summarised as follows. Firstly, the precipitative events in the automobile's technological trajectory were confirmed, which included the automobile's disruptive origin, dominant design and inflexion point. Here, the automobile's technological trajectory is consistent with a classical technological evolution. Secondly, three dominant manufacturing paradigms were confirmed and their eras were established, which are consistent with theory established in Chapter 4 of this dissertation for craftsmanship, mass production and lean manufacturing. Thirdly, the key attributes of craftsmanship, mass production and lean manufacturing were determined and their competitive advantages were established. Fourthly, the manner in which the key attributes and competitive advantages for craftsmanship, mass production and lean manufacturing evolved was established.

# CHAPTER 6
# HYPOTHESISED RELATIONSHIPS.

## 6.1 INTRODUCTION

The candidate forms and tests hypotheses in this chapter for the relationship between the three dominant manufacturing paradigms of craftsmanship, mass production and lean manufacturing. The formation and testing of the candidate's hypotheses in this chapter is a key part of the strategic argument that is mapped in Table 3 of this dissertation. The formation of the hypotheses is based on the evaluation of lean manufacturing in Chapter 5 against the theory in Chapter 4 of this dissertation. Two primary hypotheses and three sub-hypotheses are formed and tested against existing strategic, innovation and economic models. The results are evaluated and discussed.

## 6.2 HYPOTHESIS 1: SYSTEMIC MIGRATION (H1).

The candidate submits that LM is an endogenous evolution from CR and MP according to this dissertation's analytical framework. The candidate further submits that CR, MP and LM are generic to all complex technological paradigms, which observe an S-curve for technological development according to the criteria defined in this dissertation's analytical framework.

**(H1):** The weaknesses in any dominant manufacturing paradigm are exploited systematically by its successor but the aggregate strength of any paradigm remains fundamentally constant.

## 6.3 HYPOTHESIS 2: DYNAMIC WASTE THRESHOLD (H2).

The candidate submits that a dynamic waste threshold exists, which drives fundamentally the reconfiguration of the dominant manufacturing paradigms. The candidate develops **H2** in the following sections through three sub-hypotheses.

**(H2):** The dominant manufacturing paradigms evolve around a dynamic waste threshold.

### 6.3.1 Sub-hypothesis 2a: Waste as a function of dominant design efficiency (H2a).

Table 17 in this dissertation showed that the formation, emergence and development of a dominant design characterises an ordered migration in innovation focus. Section 4.4.6 (b) Dominant designs and efficiency in this dissertation explained that an emerged dominant design is inefficient inherently. Whilst an emerged dominant design is inefficient, it can be said that a formative dominant design is the least efficient (and produces the most waste) and a developed dominant design is the most efficient (and produces the least waste). Here, the candidate asserts that dominant design efficiency follows an ordered migration in product design efficiency and process efficiency, which reflects the ordered migration in innovation focus that was defined in Table 17. Product design inefficiency represents waste in product function, performance, materials and manufacturability. Process inefficiency represents waste in the productivity of the manufacturing system. Table 21 summarises the candidate's assertion about waste as a function of dominant design efficiency.

**(H2a):** The dynamic waste threshold is a function of dominant design efficiency.

***Table 21: Migration in dominant design efficiency.***
***Source: Candidate's design.***

| | | *Dominant design phase.* | | |
|---|---|---|---|---|
| | | **FORMATION** | **EMERGENCE** | **DEVELOPMENT** |
| **DESIGN EFFICIENCY** | Highest | | | **X** |
| | Middle | | **X** | |
| | Lowest | **X** | | |
| **PROCESS EFFICIENCY** | Highest | | | **X** |
| | Middle | | **X** | |
| | Lowest | **X** | | |
| | | **CRAFTSMANSHIP** | **MASS PRODUCTION** | **LEAN MANUFACTURING** |
| | | *Compatible manufacturing paradigm.* | | |

### 6.3.2 Sub-hypothesis 2b: Waste profile as an antecedent of organisational architecture (H2b).

The candidate hypothesised that the three dominant manufacturing paradigms evolve around a dynamic waste threshold **(H2)**, which is a function of dominant design efficiency **(H2a)**. The candidate further submits that the waste threshold for each dominant manufacturing paradigm has a unique profile around which the paradigm's architecture is organised **(H2b)**. Here, the candidate believes that waste has a functional purpose. Table 22 summarises the candidate's assertion about waste profiles and functions.

**(H2b):** Each dominant manufacturing paradigm has a unique waste profile around which its architecture is organised.

*Table 22: Waste profiles and functions.*
*Source: Candidate's design.*

| | CRAFTSMANSHIP | MASS PRODUCTION | LEAN MANUFACTURING |
|---|---|---|---|
| **Waste requirement.** | Open ended. | Minimal threshold. | Residual. |
| **Waste profile.** | | | |
| **Waste function.** | Enable invention, novelty and technological transformation. | Enable market establishment through standardisation and affordability. | Enable late entrants to compete through satisfying mature customer needs through continuous improvement. |
| **Limiting threshold.** | Craftsmanship is limited by the functional need for open ended waste. | Mass production is limited by the functional need for a minimal threshold of residual waste. | Lean manufacturing is limited by the amount of residual waste that can be eliminated. |
| **Hidden plant** (Candidate assertion based on Feigenbaum, 1956). | Welcome and ignored. √ | Hidden. √ | Revealed and not tolerated. x |
| **Waste trend.** | | | |
| **Efficiency trend.** | | | |

**6.3.2 (a) FUNCTIONAL WASTE.**

The candidate's submission that waste has a function is based on the logic that because waste exists it must have some purpose. Waste in the design of complex products can facilitate change (*e.g.* Gil, 2007) and waste in the productivity of manufacturing systems can facilitate flexibility (*e.g.* Koste and Malhotra, 2000). Trading-off waste with efficiency can have the effect of limiting or expanding organisational capability in exploration or exploitation (*e.g.* Porter, 1996, pp. 68-70).

**Definitions of waste.**

The candidate observed that concise definitions of waste are found in LM literature. Here, an overview is presented in order to explain the types of waste that are considered in this dissertation. Shingo identified seven primary wastes and two secondary sources of manufacturing waste during his participation in the development of LM. The seven primary wastes are classified as *muda* (Japanese for waste) and include overproduction, defects, unnecessary inventory, inappropriate processing, excessive transportation, waiting and unnecessary motion (Hines *et al*., 2008, p. 5). Ohno regarded overproduction[75] as the worse form of waste and a priority target (Monden, 1994, p. 2). The secondary sources of waste in LM are *mura* (Japanese for unevenness or variability[76]) and *muri* (Japanese for overburden) (Hines *et al*., 2008, pp. 5-7). Ortiz (2006, p. 32) reported an eighth waste in addition to LM's seven primary wastes, which is the non-utilisation of human skills and potential. Imai (1986, p. 249) reported a ninth waste in addition to LM's seven primary wastes and Ortiz's (2006) eighth waste, which is design waste. Imai's (1986) design waste is regarded by the candidate to reflect design inefficiency in the dominant design according to Table 21 of this dissertation.

**6.3.2 (b) FUNCTIONAL WASTE IN CRAFTSMANSHIP.**

According to Clark, the exploration of high-order product concepts requires freedom from process constraints. A de-focus on the organisation and productivity of manufacturing systems frees product exploration from process biases, which may enhance and crystallise product concepts that have low process change costs and the potential for high productivity (Clark 1985, p. 248). A manufacturing system focus can be counterproductive when product design challenges are fundamental (Clark 1985, p. 248; Benner and Tushman, 2003, pp. 252-253). Sandberg suggests that a focus on productivity and superior product performance can be considered to be a reactive response to product development, which may jeopardise first-mover advantages and the development of intellectual capital leverage (Sandberg, 2007, pp. 264-265). Utterback and Abernathy argue that the pre-dominant design phase of a technological trajectory requires a manufacturing system that responds easily to change, which is typified by general purpose equipment and unstandardised manual operations. The fluidity of the pre-dominant design phase means that manufacturing is organic by nature and by necessity is slack and inefficient (Utterback and Abernathy, 1975, p. 641). The CR era of the automobile personified custom design for wealthy enthusiasts. The inbuilt redundancies of CR's manufacturing system allowed design freedom (Jonsson, 2000, p. 708) and was a good fit in an environment of customised design, low volume, long lead times[77] and high cost margins (Hayes and Wheelwright, 1979, pp. 134-138).

Several authors have considered the application of LM waste elimination practices and *kaizen* in CR environments and proposed a theoretical account of how this could be achieved (*e.g.* Connor, 2001,

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75 Monden (1994, pp. 2-3) argued that four wastes exist in manufacturing, which occur in a causal hierarchy: excessive production resources, overproduction, excessive inventory, unnecessary capital investment. Monden argued that excessive production resources should be the primary focus because it is the head precursor. Monden's excessive production resources can be regarded to be aligned with Ohno's concept of overproduction (Ohno, 1988, pp. 19-20).

76 The English translation of Ohno's description is *mura* as "inconsistency" and *muri* as "unreasonableness" (Ohno, 1988, p. 41).

77 Roemer and Ahmadi (2010, p. 601) report that CR lacks responsiveness to the diminishing lead times of a mature market and is uncompetitive in this aspect. The candidate argues that long lead times may be a competitive advantage for CR products because being placed on a waiting list may enhance a product's attractiveness through a perception of prestige and exclusivity. An example within the automobile paradigm is the niche producer Ferrari, which can be regarded to employ some CR practices and produce CR products relative to mainstream producers. Ferrari achieved record sales during the 2008/2009 Global Financial Crisis (> 6000 units annually), which was attributed largely to China. Ferrari ownership within the emerging Chinese wealthy class provided a public perception of immunity to economic decline and being placed on a waiting list added to ones social standing (The world today, 2008 [radio broadcast] ABC, 891 South Australia, 18 December 2008 12.00).

Chapter 3; Rawabdeh, 2005). Here, the candidate argues that the theory presented did not recognise the cyclic nature of technological maturation and the functional purpose of waste in CR. The candidate noted empirical evidence for *kaizen*-based waste reduction activity in CR environments in Hales *et al*., who researched the effect of defect reduction efforts. Hales *et al*. (2006) found that systematic *kaizen* efforts for the reduction of waste from manufacturing defects was unsuccessful in a CR environment and was harmful to performance. The research result was attributed to the organic nature of CR manufacturing where defect knowledge was best communicated verbally and informally. The candidate believes that CR waste can be regarded as a strategic investment and cost of securing intellectual capital and first-mover advantages, which is redeemable through organisational reconfiguration as the technology is adopted and matures.

The candidate contends that unlimited waste is a strategic advantage in CR that allows wholesale exploration.

**6.3.2 (c) FUNCTIONAL WASTE IN MASS PRODUCTION.**

Ford was able to explore new ways of organising and coordinating production processes because of its single product offering, which according to Clark (1985, p. 247): "takes the product and its design as given". The exploitation of economies of scale based on the principle of "faster and more" created enormous inventory stockpiles. Ford's average departmental inventory in 1926 was 10 days supply with some components and materials having 31 days' supply. Additionally, Ford had 6 days' supply in transit as a protective float, which was enough to manufacture 48,000 completed vehicles (Ford, 1926, p. 117). Ford's large inventories provided a strategic buffer against supply risks in a period of rapid market expansion with ostensibly inexhaustible demand (Zsidisin and Ellram, 2003, p. 15). The waste from large inventories and inspection based quality control was referred to by Shingo as "absolute evil[78]" in LM (Shingo, 1991, p. 43). Moreover, Ohno likened MP factories to giant warehouses. Here, the candidate argues that MP's inventory-based waste had the strategic function of facilitating the pursuit of economies of scale, which was appropriate for the stage of technological development of the automobile paradigm. Moreover, MP's waste would provide paradoxically Toyota a means for the reconfiguration of MP to LM, which would allow Toyota to compete against the MP incumbents. The candidate believes that waste in MP and LM has different functional roles, which are embedded within the automobile paradigm's technological trajectory and reflected in the configuration of manufacturing systems.

Henry Ford was not wasteful deliberately. Indeed, Ford dedicated an entire chapter in his text to the explanation of MP's approach towards waste (Ford, 1926, Chapter 8). Here, the candidate argues

[78] Shingo's aggressive attitude towards inventory is reflected in contemporary LM discourse. *E.g.* Takeda (2006, p. 48) describes inventory as the "root of all evil".

that Henry Ford's definition of waste and its treatment was consistent with MP configuration and the stage of the automobile paradigm's development. Ford's basic principle was that "materials cost nothing" and the focus of waste reduction should be on minimising human labour (Ford, 1926, p. 93). Whilst it could be argued that this attitude reflected a period of abundant natural resources, Ford's vision was founded the logic that "conserving resources by withdrawing them from use is not a service to the community" and "we want to get full value out of labour so that we may be able to pay it full value" (Ford, 1926, p. 93). Here, material waste is delineated from labour waste in that materials have no value until they are processed. Ford regarded materials as salvageable whereas "time as human energy" was not (Ford, 1926, p. 114). According to Ford (1926, p. 114): "it is a waste to carry so small a stock of materials that an accident will tie up production". A degree of material waste is tolerated as being unavoidable, which may be recycled provided the labour involved justified the case (Ford, 1926, p. 96). Here, the candidate argues that MP requires a minimum waste threshold to function.

The candidate contends that a minimum threshold of waste is a strategic advantage in MP that allows economies of scale.

**6.3.2 (d) FUNCTIONAL WASTE IN LEAN MANUFACTURING.**

The post-dominant design era in which LM emerged was characterised by a greater consumer emphasis on product choice, performance features such as ease of operation, ride smoothness, comfort, convenience, power, quality and a growing expectation of value for money (Clark, 1985, p. 246). MP's reliance on economies of scale and its reactive quality control strategy was emerging as a "false trade-off" between cost and quality (Porter, 1996, p. 69). *I.e.* higher quality required more inspection and re-work which drove up costs. Moreover, larger economies of scale to achieve lower costs increased the need for inspection and re-work. LM's innovation of a synergistic relationship between cost reduction, higher quality and mass customisation allowed Toyota to exploit the inherent waste in MP in two key ways. Firstly, by the elimination of inventory-based and reactive quality-based waste. Secondly, through rapid product launch that has heavy integration of manufacturability considerations into product design, which enables rapid ramp-up to flow production. According to Imai (1986, p. 249), the greatest "economization" in new product introduction occurs through the shortest transition to stabilised processes.

The candidate contends that the inherent waste in MP that is exposed as deviation to perfect flow is a strategic advantage in LM, which allows continuous productivity improvement.

### 6.3.2 (e) PUSH, PULL, PRODUCTION VOLUME AND BUFFERING METHOD.

Section 4.4.3 (e) Technology-push/customer-pull continuum in this dissertation posited LM as an exemplar of customer-pull. Here, the candidate believes that CR can be confirmed as the exemplar of technology-push through its waste profile.

**Craftsmanship as an exemplar of technology-push.**

Hopp and Spearman reduced push-production and pull-production to their essence. Pull- production is a system that limits explicitly waste[79] and conversely push-production allows limitless waste (Hopp and Spearman, 2004, p. 142). The candidate has argued that CR is predisposed to technology-push and has a profile of limitless waste. Here, the candidate submits CR as an exemplar of technology-push.

**Mass Production as an intermediary between Craftsmanship and Lean Manufacturing.**

Hopp and Spearman (2004) explain that stable production conditions are not the norm and that buffering against internally and externally imposed production variation is an effective management method. Ohno bypassed the high inventory levels of MP by adjusting output through capacity flexibility (Ohno, 1988, p. 95). LM's small lot sizes, quick set-up and modular production cells allow adjustment to demand fluctuations, which is moderated by production levelling, product development strategies[80] and marketing strategies[81]. Hopp and Spearman explain that the result of Ohno's strategy was to transfer MP's inventory buffering to LM's capacity buffering[82] (Hopp and Spearman, 2004, p. 145). A third buffering method exists in addition to inventory and capacity buffering, which is time buffering (Hopp and Spearman, 2004, p. 145). The candidate argues that time buffering identifies with CR for two reasons. Firstly, CR's market is characterised by consumer's that have an expectation and tolerance for long production lead times. Secondly, inventory or capacity buffering is of little benefit in this environment. The candidate believes that the position of the dominant manufacturing paradigms along the technology-push/customer-pull continuum can be confirmed through their waste profiles, buffering method and demand conditions. The candidate argues that CR has insignificant volume and a strategic disregard for waste, capacity and inventory buffering. MP exploits strategically growth stimulating volume through inventory buffering. LM exploits inventory elimination through capacity buffering in a slow growth market. Table 23

[79] Hopp and Spearman (2004) did not use directly the term waste but "work in process". The candidate interpreted work in process as meaning inventory, scrap and re-work.

[80] Toyota develops and releases new products according to a schedule that is designed to minimise production variation (Liker, 2004, p. 123).

[81] Toyota engage in "aggressive selling" in order to boost demand for models with flagging sales, which uses databases to target model specific customers and repeat buyers (Womack *et al*., 1991, p. 67).

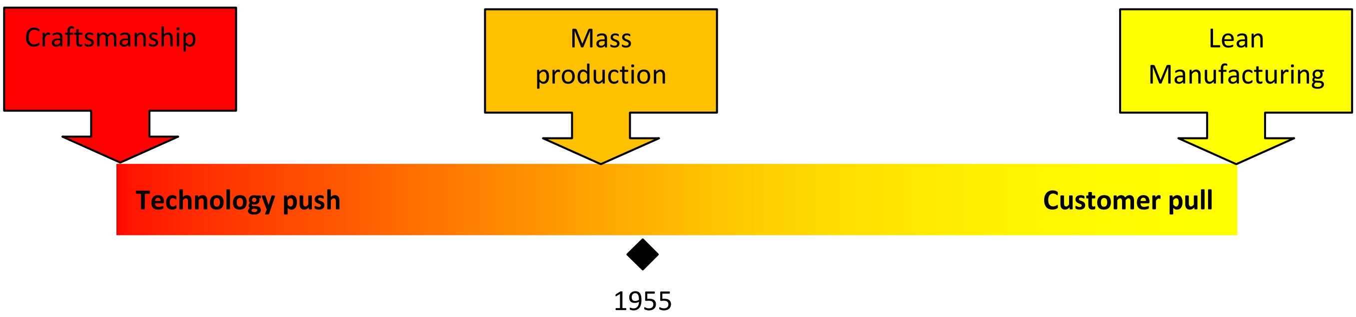
[82] Whilst LM uses capacity buffering it is regarded as a bufferless system. The purpose of demand levelling is to avoid capacity adjustment, which constitutes waste. Steady-state flow is difficult to achieve and LM is known pragmatically as a "best buffer" system (Hopp and Spearman, 2004, p. 147).

summarises the candidate's contention. Figure 9 shows the candidate's confirmed technology-push/customer-pull continuum.

*Table 23: Waste profile, buffering method and demand conditions.*
*Source: Candidate's design.*

| | CRAFTSMANSHIP | MASS PRODUCTION | LEAN MANUFACTURING |
|---|---|---|---|
| **Waste profile.** | Organic push-production with unlimited waste. | Organised push-production around minimal waste threshold. | Organised pull-production with elimination of residual waste. |
| **Buffering method.** | Time (based on product novelty). | Inventory (based on residual stock). | Capacity (based on demand levelling). |
| **Demand condition.** | Insignificant volume. Unstable market. | High volume. Rapid market growth. | High volume. Slow market growth. |

*Figure 9: Confirmed fully technology-push/customer-pull continuum*
*(at dominant manufacturing paradigm level).*
*Source: Candidate's design.*



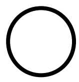

### 6.3.2 (f) WASTE AND ARCHITECTURAL CONFIGURATIONS.

Chapter 5 in this dissertation revealed that the three dominant manufacturing paradigms have different architectural configurations. The candidate then argued that the architectural configurations are organised around the unique waste profiles of the dominant manufacturing paradigms. Here, the candidate shows that each configuration allows waste to execute its unique function and in doing so the dominant manufacturing paradigm's architecture expresses physically and facilitates its waste profile.

**From flexibility to rigidity through inverse variants.**

The candidate argues that the configurations in organisational architecture that arise from the dynamic waste threshold show a trend from flexibility to rigidity, which mirrors the productivity, innovator's and proactivity dilemmas. The candidate submits that the architectural configurations of the three dominant manufacturing paradigms can be summarised: CR has indeterminate and organic[83] architecture whilst MP and LM are opposites[84] of each other. Table 24 shows the candidate's summary.

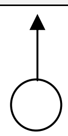
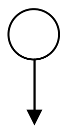
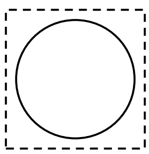
*Table 24: Summary of three dominant manufacturing paradigm's architecture. Source: Candidate's design.*

| | *Pre-dominant design* | *Post-dominant design* | |
|---|---|---|---|
| | **CRAFTSMANSHIP** | **MASS PRODUCTION** | **LEAN MANUFACTURING** |
| **Pictorial representation.** | **Indeterminate** (organic)  | MP is the opposite of LM | LM is the opposite of MP |

**Indeterminacy to determinacy through a structural compass.**

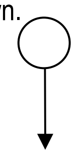
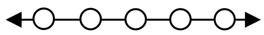
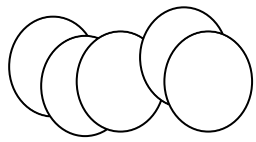
Whilst the pre-dominant design organic architecture of CR is indeterminate practically, the post-dominant design opposite relationship between MP and LM is demonstrated by juxtaposing the key attributes of MP and LM that were revealed in Chapter 5 of this dissertation. Table 25 shows the juxtaposition of the key attributes for MP and LM in their ideal state.

*Table 25: Juxtaposition of the key attributes for mass production and lean manufacturing. Source: Candidate's design.*

| **Strategic feature.** | **MASS PRODUCTION** | **LEAN MANUFACTURING** | **Comment.** |
|---|---|---|---|
| **Manufacturing system.** | | | |
| Direction of production flow. | Push.  | Pull.  | Pull and push have opposite flow in production signals. |
| Buffering strategy. | Buffered. | Unbuffered. | |
| Buffering method. | Inventory.  | Capacity (if required).  | LM strives for level demand, which results in an inventory-less state. If demand variation exists, capacity buffering is used. |
| Lot size. | Large batch. Intermittent production. | Single piece. Continuous flow. | In practice, single piece is described as "small lot". |
| Changeover frequency. | Low. | High. | |
| Changeover duration. | Slow (external). | Fast (internal). | |
| Operator/work | Work to operator. | Operator to work. | |

83 Utterback and Abernathy (1975, p. 641) also associated CR with "organic systems".

84 Ohno (1988, p. 107) was impressed with how Ford "repeatedly came up with brilliant inverse conceptions", which motivated Ohno to "view things upside down". Ohno (1988, p. 95) admitted that LM is "in fact the opposite of the Ford system (MP)".

| | | | |
|---|---|---|---|
| interaction. | | | |
| Machinery design. | Dedicated, single purpose.<br>Multi-unit operation. | Generalised, multiple purpose.<br>Multi-process operation. | |
| Manufacturing layout. | Isolated island.<br>Semi-synchronised. | Integrated U shape.<br>Synchronised. | |
| Assembly layout. | Physical (push) conveyor. | Invisible (pull) conveyor. | |
| Normal line stoppage. | End of run. | At operator discretion. | |
| Automation focus. | High. | Low. | |
| Capital investment. | High. | Low. | |
| Investment focus. | Plant. | People. | |
| Supplier base. | Develop internal capability.<br>Make in-house. | Leverage external capability.<br>Supplier integration. | |
| Quality focus. | Detection (reactive). | Prevention (proactive). | |
| Quality responsibility. | Specialist (external) inspector. | Generalised (internal) self-inspection. | |
| Quality control method. | Human measurement.<br>Reactive output control. | Autonomation.<br>Proactive input control. | |
| Waste focus. | Labour first, materials second. | Materials (inventory) first, labour second. | |
| Efficiency method. | Quantity and speed.<br>Maximum output. | Continuous and level.<br>Tact. | |
| **Management.** | | | |
| Management structure. | Vertical, centralised, top down.<br> | Horizontal, integrated.<br> | |
| Organisational structure. | Segregated, functional departments. | Integrated, cross-functional teams. | |
| Operator skills. | Narrow and isolated (fixed role).<br> | Broad and integrated (variable, rotated roles).<br> | |
| Operator communication. | 1 way. | 2 way. | |
| Communication direction. | Vertical down. | Horizontal across. | |
| Operator initiative. | Not sought. | Sought. | |
| Knowledge locus. | Centralised, experts. | Disseminated, multi-skilled. | |
| Decision method. | Autocratic. Individualistic. | Consensus. Collective. | |
| Decision locus. | Centralised, top down. | Integrated, horizontal. | |
| Operator investment. | Low. | High. | |
| Operator responsibility. | Narrow. | Broad. | |
| Scheduling. | Centrally coordinated, variable.<br>Plan to grow demand. | Self-regulating, continuous flow.<br>Plan to level demand. | |
| Materials handling. | Bulk. Stored. | Just-in-time. | |
| Improvement responsibility. | External specialist. | Internal generalised. | |
| **Market strategy.** | | | |
| Product volume. | High volume, growing | Low(er) volume, level | |

| | | | |
|---|---|---|---|
| | demand. | demand. | |
| Product variety. | Single or minimal product offering. | Mass customisation. | |
| Primary innovation focus. | Product. | Process. | |
| Primary innovation mechanism. | Radical, step or bundled change, intermittent. | Incremental, accumulated and continuous. | |
| Primary innovation responsibility. | Centralised, experts. | Disseminated, multi- skilled. | |
| Primary innovation driver. | Internal customer (stakeholders). | External customer (consumer). | |
| Relationship to customer. | Producer knows best. | Consumer knows best. | |
| Cash flow. | Strive to grow rapidly. | Strive to normalise then grow incrementally. | Pure Fordism argues that massive corporations benefit society (monopoly theory) whilst Lean Manufacturing ideology views excessive growth as potential waste (uncontrolled production variation). |
| Barriers to competitors. | Sunk cost: tangible, physical plant, tooling and product knowledge. | Sunk cost: intangible, training, culture and process knowledge. | |

### 6.3.3 Sub-hypothesis 2c: Innovation as an outcome of organisational architecture (H2c).

The candidate hypothesises in this section that the resultant architectures of the three dominant manufacturing paradigms from their unique waste profiles have the net outcome of facilitating the dominant innovation object and mechanism that is appropriate for the contextual conditions the paradigms operate under.

**(H2c):** The dominant innovation object and mechanism within a dominant manufacturing paradigm is an outcome of its organisational architecture.

#### 6.3.3 (a) ARCHITECTURE AND INNOVATION.

The candidate has argued that unique waste profiles are an antecedent of organisational architecture. Here, the candidate argues that the organisational architecture of the dominant manufacturing paradigms mirrors and propels its dominant innovation object and mechanism as a self-reinforcing system. Insights into the interaction between architecture and innovation can be revealed by examining the information and communication flows, power distributions, learning mechanisms and cultures within the three dominant manufacturing paradigms.

#### 6.3.3 (b) INNOVATION WITHIN A CRAFTSMANSHIP ARCHITECTURE.

The experimental nature of CR means that profound process knowledge is lacking inherently, which makes process innovation and systemisation difficult. CR's architecture allows the pursuit of novelty and intellectual capital generation, with waste acting as a project safeguard in a climate of uncertainty (Gil, 2007, pp. 980-984; Langley *et al*., 2009, p. 6).

The candidate submits that the organic and indeterminate nature of CR's architecture facilitates transformational innovation in product paradigms and radical innovation in high-order product concepts.

**6.3.3 (c) INNOVATION WITHIN A MASS PRODUCTION ARCHITECTURE.**

Here, the candidate argues that Ford's MP architecture facilitates radical innovation and is unconducive to continuous incremental improvement.

**Scale and sunk costs.**

Henry Ford lamented the high expenses of changing current standards, which impacted greatly tooling and resulted in extensive changeover planning and lost production time (Ford, 1926, pp. 87-89). Changes in MP were a significant and infrequent event, which made it important to take advantage of the opportunity by making radical or bundled changes. Cusumano observed that the significance and infrequency of changes in MP fostered radical innovation as a stepped, "one time improvement" strategy that did not facilitate continuous incremental improvement (Cusumano, 1988, p. 38). Utterback and Abernathy suggest that the large investment in the mass production of a single product offering means that small changes can be costly because of the explicit relationship between product designs and dedicated manufacturing processes. Here, high sunk costs become a barrier to minor improvement activities (Utterback and Abernathy, 1975, p. 642).

**Centralised innovation locus.**

Decision making in MP rests with a dominant few and tends to be strategic in nature. Centralised decision making allows proactive opportunistic behaviour, which can accommodate radical departures from the existing condition with far reaching innovation outcomes (Fredrickson, 1986, p. 284). Innovation in MP has an top-driven executive locus that broadcasts innovation throughout the lower echelons and uses specialists for its execution (Siggelkow and Rivkin, 2006, p. 779).

**Barriers to continuous improvement.**

The candidate argues that the MP producer adopts the attitude that they know best and do not integrate customers into innovation planning. The producer first attitude intensifies consolidation and compatibility efforts in product architecture in order to optimise economies of scale, which is at the expense of refinement of product component and process elements. The candidate believes that their argument is consistent with the phase of dominant design development and market evolution. Here, the candidate argues that the centralised innovation locus and focus on the mass replication of a fixed product manifests barriers to continuous incremental improvement, which are reflected in

MP's organisational architecture. The communication stream for innovation discourse is one-way top-down and does not solicit the input of customers, external suppliers or production operators. According to Levinthal and March, communication is further impeded by MP's organisational decomposition into functional departments, which segregates experience and fosters specialisation (Levinthal and March, 1993, pp. 97-98). Moreover, cross-communication in production is impeded by "isolated islands" of manufacturing, which are dislocated largely from assembly (Ohno, 1988, p. 213). Improvement opportunities are masked by piles of semi-synchronised inventory in the presence of a culture that does not value collective improvement initiatives. The narrow job roles of production operators demand steadfast compliance and prohibit deviation or creativity.

The candidate contends that MP innovation is still in a fundamental technology-push phase and is generated primarily for the producer's benefit through radical stepped-changes in the architectural integration of the product.

#### 6.3.3 (d) INNOVATION WITHIN A LEAN MANUFACTURING ARCHITECTURE.

Ohno made three key observations about how MP's architecture impeded *kaizen*-based production flow. Firstly, the isolated islands of MP made cross-communication and coordination difficult (Monden, 1994, Chapter 11). Secondly, the narrow job roles of MP were dehumanising and did not promote collaboration, but could be addressed through a team approach where harmony and individual input is valued highly (Ohno, 1988, p. 25). Thirdly, information[85] must flow JIT and "excessive information must be suppressed" in order to ensure a naturally occurring production schedule (Ohno, 1988, p. 50). Ohno realised the importance of communication, information, visual clarity, collective effort and teamwork in the achievement of production flow and *kaizen*. This point is captured by Takeda (2006, p. 134): "If everyone acts independently, *kaizen* does not take place". Ohno proceeded to reconfigure Toyota's pre-LM architecture that was based on MP towards the optimal facilitation of customer-pulled production flow with *kaizen*. The isolated islands of MP were replaced by integrated cells, which allowed cross-communication and visual observation of production outcomes. Ohno complemented the physical reconfiguration of machinery with the reconfiguration of the architecture for management hierarchy and communication flow. Toyota's management structure was flattened by the removal of superfluous tiers and communication flow was made ubiquitous. Moreover, Ohno empowered production operators to engage in *kaizen* and promoted teamwork in an intimate organisational environment (Ohno, 1988). Ohno's reconfigurations had three key outcomes that supported his objectives. Firstly, integrated production cells facilitate cross-communication and visual clarity of process improvement opportunities.

[85] Information must flow in Tact, with too much or too little representing waste. The same concept applies in the delineation between "stores" and "storage spaces". Stores are connected to downstream processes by addresses, part numbers, allowable quantities *etc.* (*i.e. kanban*) and are therefore framed as a "tool for information management". Storage space is the opposite (*i.e.* warehouse) and is wasteful because it provides no useable information (Takeda, 2006, pp. 103-108).

Secondly, the structural change in infrastructure was a powerful inducer of a customer focussed culture (Kok and Biemans, 2009, p. 524 p. 517). Thirdly, operator empowerment with democratised responsibilities had the effect of lowering inhibitions, which provided comfort in collaborative participation (Dombrowski *et al*., 2007. pp. 194-195).

**Decentralised power.**

The candidate argues that according the theory of Bloomfield and Best, Ohno's role in organisational reconfiguration made him a powerful actor and node in the new Toyota network, which incited a translation of organisational goals to suit his manufacturing system. LM's architecture and the objective of production flow resulted in the construction of new interests and power distributions (Bloomfield and Best, 1992, pp. 535-536). Furthermore, according to Fredrickson, Ohno's reconfiguration had the effect of decentralising power (Fredrickson, 1986). Moreover, according to Parkin, Ohno's reconfiguration legitimised customer-pull as the new business model and provided a template for how actors will be enrolled in an explicit alliance (Parkin, 1994, pp. 206-207).

**Disseminated information locus with process focus.**

Whilst MP centralised and concentrated information, LM disseminated information. A key outcome from *kanban* and Tact information flow was that relevant information is contained between *kanban* points and is concentrated within lower management (production managers, cell team leaders *etc*.). Wasteless production flow implies that information content and provision must be restricted to immediate operational specificity (Takeda, 2006, p. 65). Ohno's reconfigurations had the effect of disseminating the locus of decision making and providing a focus on manufacturing processes that is based on relevant information. Ohno (1988, p. 20) maintained consistently a "plant first principle" on the premise that production operations are the source of information for management in LM.

According to Siggelkow and Rivkin, the net result in LM from decentralised power and information within a context of highly interdependent processes is inertia in enterprise-wide, low-level production-driven innovation (Siggelkow and Rivkin, 2006, p. 791-792).

Here, the candidate argues that the process focus for innovation in LM is intensified by its other features. Visual management makes disruptions to process flow obvious and highlights improvement opportunities. Mass customisation further concentrates a process focus as processes become relatively generic and their object relatively variable. Moreover, the candidate argues that product development further sharpens a process focus. Toyota applied Ohno's principles of empowered teamwork based on cross-communication and relevant information to product development (Morgan and Liker, 2006). The candidate points out that product development can be regarded as a process which is between the *kanban* points of external customer and manufacturing system. Here, a process focus is enhanced because product development is perceived *per se* as an integrated process with manufacturing and that manufacturing considerations in product development constitute relevant data.

**Spatial and temporal biases.**

The candidate argues that enterprise-wide inertia in low-level production innovation compounds as competencies are enhanced and the demands for more efficient synchronisation increase. Levinthal and March explain that the elimination of failures and installation of favourable process outcomes grows confidence in the mastery of processes (Levinthal and March, 1993, p. 110). According to Miller *et al.*, confidence grows further as tacit skills become transferred between operators (Miller *et al.*, 2006, p. 709). Siggelkow and Rivkin show that in this environment "parochial interests" develop and increasingly become a factor in decision making (Siggelkow and Rivkin, 2006, pp. 791-792). Moreover, the restriction of interaction between *kanban* contact points and the intensification of mutual purpose acts to inhibit learning from divergent external sources (Sorenson, 2003, pp. 458-459). Here, there is a tendency to discount future problems and give priority to short-range consequences (Linestone, 1984, p. 50).

According to Levinthal and March, the demands of synchronised activity in LM result in learning that has **spatial** and **temporal biases** akin to "myopia" because of the concentration on the immediacy of neighbourhood and events (Levinthal and March, 1993, p. 110).

**Continuous incremental improvement.**

The candidate argues that continuous incremental improvement becomes ingrained as an organisation gravitates towards a steady-state. Here, the candidate draws attention to Toyota's market context. Low-level disseminated innovation with spatial and temporal biases is consistent with the candidate's theory of dominant design development, which is characterised by process efficiency and low-order product innovation. Toyota's locus and objects of innovation produce an outcome that is consistent with competency enhancing continuous incremental improvement (Gatignon *et al.*, 2002). Continuous incremental improvement is enhanced further by a strategic focus on the selection of process improvement projects that are integrated with project management infrastructure and existing production operations (Zhang *et al.*, 2008, p. 50). Toyota's low growth market condition provides predictability because of gradual shifts in consumer consumption patterns, which affords stability and reduces risk (Langley *et al.*, 2009, p. 6). According to Chiesa *et al.*, the stability from a low risk environment and mature enterprise-wide *kaizen* culture tend to impose social control against the selection of projects that conflict with entrenched values (Chiesa *et al.*, 2009, p. 438). Here, radical innovation is subject increasingly to sociological analysis in addition to scientific and technical analysis (Callon, 1987, p. 100).

According to Utterback and Abernathy, transformational and radical innovation is difficult to accommodate and perceived as disruptive to current practices in an intensely systemic stage of integrated organisational and product architectures (Utterback and Abernathy, 1975, pp. 646-647).

**Incremental policy deployment.**

Whilst disseminated *kaizen* can produce significant micro-exploration in the production domain, it can reduce organisational exploration as a whole. According to Siggelkow and Rivkin, the relegation of exploration locus from executive management to lower levels empowers the lower levels to consider extensively options in finding solutions to their specific problems[86], which increases their autonomy in screening out solutions that do not suit parochial interests. Here, low level inertia in localised innovation can have the effect of stifling high order strategic exploration (Siggelkow and Rivkin, 2006, pp. 791-792). According to Liker, Toyota strives to counter potential biases in innovation towards low-order parochial interests through a “policy deployment” mechanism[87], which intends to broadcast and embed high-order strategic agendas throughout the lower echelons (Liker, 2004, p. 262). Here, the candidate argues that policy deployment gravitates towards steady-state incremental adjustment, because of the systemic response and feedback time required to gather inertia and deploy policies in a complex system. Rivkin explains that the leveraging of organisational policy and learning in a complex system is limited by the need for accurate information and its accurate replication (Rivkin, 2000). The candidate argues that LM’s highly interdependent and path dependent information streams in a network of disseminated decision points allow little scope for error, because the collective synchronicity of the whole is sensitive to individual actions. *I.e.* flawed micro-decisions may be amplified throughout the network to a point of saliency (Rivkin, 2000). Policy deployment errors are waste within a LM context, which implies that the least waste is generated through flow sensitive policy adjustment. Here, the candidate contends that information continuity is most efficient under incremental policy deployment. Moreover, the productivity and innovator’s dilemmas are echoed in that Toyota’s strength through organisational integration is a weakness for accommodating radical or transformation change. *I.e.* whilst the convergence of knit tightly activities that achieve flow can create barriers to competitor mimicry, the convergence in itself can become an internal barrier by rendering the system unresponsive to change (Rivkin, 2000). The candidate adds that two further factors of political bargaining and reflexive crisis reaction compound incremental policy deployment. Forced *kaizen* from line stoppages demands solutions that are characterised by political bargaining. Klein explains that LM decisions must be considered within the context of the upstream and downstream customers in the production flow, which has the effect of limiting

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86 The candidate believes that an extreme manifestation of parochial interests is an emerging LM hybrid called Low Cost Intelligent Automation (LCIA). Here production operators engage actively in the customisation, design and procurement of the production equipment they will be using.

87 Toyota calls policy deployment *hoshin kanri* (Liker, 2004, p. 262). *Hoshin kanri* development is often attributed to Professor Akao (Australian Quality Council, 1994, p. 4-14).

genuine autonomy (Klein, 1989, p. 64). The candidate argued previously that decisions made through political bargaining within imposed constraints tend to become incremental and focus on risk reduction in highly specific and localised needs (parochial interests). According to Fredrickson, in this environment it is less likely that high-order strategic decisions and innovations will be recognised[88] and more likely that they will be ignored (Fredrickson, 1986, p. 284). Accordingly, the candidate argues that LM's self-monitoring autonomation mechanism reflexively forces crisis reaction in the executive domain. Here, Fredrickson argues that the need for precise remedial solutions concentrates strategic decisions on the tightening of organisational processes, which further engenders continuous incremental improvement through stabilisation of the *status quo* (Fredrickson, 1986, p. 284). According to Lindblom, LM can be regarded to represent a complex political democracy, which simplifies decision making through incremental policy adjustment (Lindblom, 1959, p. 84). Furthermore, Das *et al*. explain that the heavy sunk costs in the development of human capital through learning and acculturation can become a liability when restructuring in learning and integration is required (Das *et al*., 2006, p. 568). Here, the candidate argues that in extreme expression the process of LM can displace its goals. Fredrickson explains that the process of LM can become an end in itself rather a means to its end (Fredrickson, 1986, p. 284).

The candidate has argued that LM's architecture represents a complex, self-reinforcing synchronous system, which is responsive increasingly to incremental adjustment.

**Conservatism.**

The candidate argues that LM's architecture and *kaizen* culture can result in conservatism. Levinthal and March (1993, p. 108) explain that architectures that demand rapid acculturation and socialisation reduce exploratory capability because of decreasing capitalisation from individual deviance. Thomas-Hunt *et al*. found that in circumstances where there is high social connection within working groups, the socially isolated minority receive typically negatively biased evaluation and unrecognised validity. Negative evaluation is likely to occur despite the socially isolated majority participating typically more and contributing greater unique and divergent knowledge as a means of countering their lower social status (Thomas-Hunt *et al*., 2003, pp. 474). Here, the preservation of social and cultural continuity is important. According to Dombrowski *et al*. (2007. pp. 194), architectures that facilitate disseminated and democratised incremental innovation can develop a culture where people are "generally unwilling both to suggest radical ideas and to shake up existing processes". The candidate notes that conservatism resonates with the national Japanese context, as part of a "national duty of conformity" (Foreign Correspondent, 2010). The candidate draws

[88] Toyota use the 5 whys mechanism to provoke strategic solutions, which will be expounded in Chapter 8 of this dissertation.

attention to a Japanese saying: “the nail that stands out should be hammered back in place” (Foreign Correspondent, 2010).

The candidate has argued that LM’s architecture promotes conservatism.

**Process rationalisation.**

Whilst Ford’s primary rationalisation object was its product range, Ohno saw the enterprise’s processes as the primary rationalisation object (Ohno, 1988, p. 114). Here, the candidate argues that LM’s objective is to rationalise the enterprise into a steady-state equilibrium, which controls its demand and production environments. According to Ohno (1988, p. 41): “If the meaning of “defective” goes beyond defective parts to include defective work, the meaning of ”100% defect-free products” becomes clearer. In other words, insufficient standardization and rationalization creates waste (*muda*), inconsistency (*mura*) and unreasonableness (*muri*) in work procedures and work hours that eventually lead to the production of defective products.”

The candidate has argued that LM’s architecture promotes gravitation towards steady-state equilibrium, which represents the most productive rationalisation of the enterprise’s processes.

**6.3.3 (e) THE INSIDIOUS PLANT.**

The candidate will develop fully and submit in Chapter 7 of this dissertation their novel concept of the proactivity dilemma. Here, the candidate asserts a relationship between waste, innovation and proactivity as a step towards the development of the proactivity dilemma. The candidate’s fundamental contribution in this section is the novel submission of an insidious plant, which is related directly to Feigenbaum’s (1983) hidden plant.

The candidate submits that whilst Feigenbaum’s (1983) hidden plant is revealed and eliminated progressively, a parallel insidious plant manufactures increasingly hidden barriers to exploratory innovation.

**Hidden plant as a barrier to continuous incremental improvement.**

The candidate argues that the hidden plant occurs pre-dominant design and manifests in the architectures of CR and MP as a barrier to continuous incremental improvement

**Insidious plant as a barrier to radical and transformational innovation.**

The candidate argues that the insidious plant occurs post-dominant design and manifests in the architecture of LM as a barrier to radical and transformational innovation.

**Waste, innovation and proactivity.**

The candidate argues that the hidden and insidious plants allow waste to execute its strategic function. Here, waste can play contradictory roles by allowing a proactive focus on exploration or exploitation. The candidate believes that the hidden plant facilitates exploration because it installs barriers to process integration. Conversely, the insidious plant removes barriers to process integration and facilitates exploitation through integration and stability. Paradoxically, it pays CR and MP producers to be in ignorance of the hidden plant and it pays the LM producer to be blind to the insidious plant. The candidate adds finally the contention that the degree to which a LM producer can reveal and act upon the insidious plant will affect their sustainability. Table 26 summarises the candidate's contention about the insidious plant. Table 27 summarises the relationship of organisational architecture to dominant innovation mechanism and object.

***Table 26: Migration in hidden plants.***
***Source: Candidate's design.***

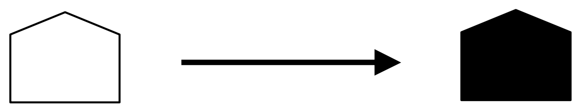
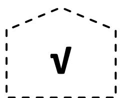
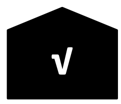
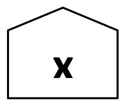
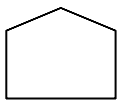
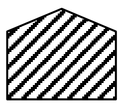
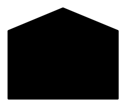
<table>
<tr><th></th><th>CRAFTSMANSHIP</th><th colspan="2">MASS PRODUCTION</th><th>LEAN MANUFACTURING</th></tr>
<tr><td></td><td colspan="2">Pre-dominant design</td><td colspan="2">Post-dominant design</td></tr>
<tr><td>WASTE FUNCTION.</td><td colspan="2">Allow exploration through inefficiency.</td><td colspan="2">Allow exploitation through efficiency.</td></tr>
<tr><td>PLANT MIGRATION (hidden to insidious).</td><td colspan="4"><br>Feigenbaum (1983) hidden plant. — Insidious plant.</td></tr>
<tr><td>PLANT FUNCTION.</td><td colspan="2">Install barriers to integration and continuous incremental improvement.</td><td colspan="2">Remove barriers to integration and continuous incremental improvement. Install barriers to radical innovation.</td></tr>
<tr><td>PROACTIVITY BENEFIT.</td><td colspan="2">Facilitates exploratory focus by blinding the enterprise to exploitation opportunities.</td><td colspan="2">Facilitates exploitative focus by blinding the enterprise to exploratory opportunities.</td></tr>
</table>

***Table 27: Relationship of organisational architecture***
***to dominant innovation mechanism and object.***
***Source: Candidate's design.***

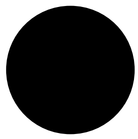
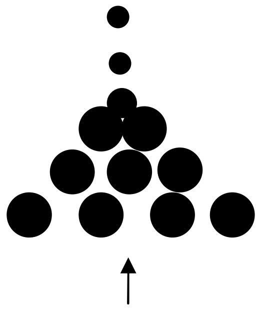
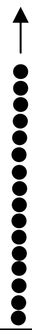
<table>
<tr><th></th><th>CRAFTSMANSHIP</th><th>MASS PRODUCTION</th><th>LEAN MANUFACTURING</th></tr>
<tr><td></td><td>Pre-dominant design</td><td colspan="2">Post-dominant design</td></tr>
<tr><td>Dominant architectural features (plant).</td><td>Organic and indeterminate.</td><td>Centralised top down, isolated islands linked to semi-flowing final assembly. High internal self-sufficiency in materials and IP.</td><td>Horizontally integrated synchronised flow (integrated U shaped cells). High supply chain integrated and interdependence. External IP leveraging.</td></tr>
</table>

| | | | |
|---|---|---|---|
| Dominant architectural features (information: locus and channel). | Organic and indeterminate. | Centralised outside of production. Top down, one way from expert, with strategic/macro view. Customer, supplier, operator input not solicited. | Contained between *kanban* points with JIT information delivery. Disseminated throughout organisation. 2 way communication (in cells and with external customers) with operator input solicited. |
| Dominant innovation drivers resulting from architecture. | Creation of core concepts.<br><br>Product focus.<br><br>Specification flexibility.<br><br>Ability to cope with high risk. | Architectural compatibility.<br><br>Product tending to process focus.<br><br>Expensive dedicated long-run tooling tends to big changes *i.e.* "get money's worth" in change/bundle changes. Incremental improvement suggestions (from operators) forsaken. | Systemic integration and optimisation.<br><br>Process tending to customer focus.<br><br>Operator autonomy and continuous improvement in internal customer satisfaction, based on high predictability. Attention tends to refinement and integration of existing processes and products within operator domain. Coordination relies on collective self - synchronised production flow. |
| Dominant locus of decision making and innovation opportunity. | Organic and indeterminate. | Top concentrated. | Low disseminated. |
| Innovation execution. | Inspired entrepreneurship | Confined to segregated specialists. | Enterprise-wide teamwork. |
| Dominant innovation object and priority. | 1) Product: paradigm.<br><br>2) Product: architecture. | 1) Product: architecture and components.<br>2) Process. | 1) Process.<br><br>2) Product: component. |
| Dominant innovation mechanism. | Transformational single events. | Radical intermittent steps. | Incremental continuous accumulation. |
| **Hidden plant (waste)** (Feigenbaum, 1983). | Welcome and ignored   | Hidden   | Revealed and not tolerated   |
| **Insidious plant. (exploration barrier).** | Revealed  | Partially hidden  | Hidden  |

### 6.3.3 (f) PRODUCTION FLOW AS A MIRROR FOR THE DOMINANT INNOVATION MECHANISM.

The candidate observed that the dominant innovation mechanism is reflected in the fundamental nature of the production flow for the three dominant manufacturing paradigms. CR production flow can be symbolised by large and unique events. MP can be symbolised as a state of semi-flow, where large and intermittent lots of manufactured components are forced and bundled together for a position on a semi-synchronised assembly conveyor. Here, MP's underlying step change approach can be imagined to be striving for continuity. LM is symbolised by the continuous synchronised flow of the smallest possible production increments. Table 28 summarises the candidate's relationship between production flow and dominant innovation mechanism.

***Table 28: Mirror effect of production flow and dominant innovation mechanism. Source: Candidate's design.***

| | **CRAFTSMANSHIP** | **MASS PRODUCTION** | **LEAN MANUFACTURING** |
|---|---|---|---|
| | *Pre-dominant design* | | *Post-dominant design* |
| Pictorial representation of production flow. |  |  |  |
| Flow description. | Significant, one-off unique *ad hoc* event. | Large intermittent steps, bundled together. Some degree of continuous accumulation with advent of conveyor. | Continuous, regulated flow reduced to smallest increments. |
| Dominant innovation mechanism. | Transformational single events. | Radical intermittent steps (tending to continuous incremental accumulation). | Continuous incremental accumulation. |

**6.4 HYPOTHESIS TESTING.**

The candidate applies three tests in this section that test theoretically the submitted hypotheses. The hypotheses are evaluated against existing strategic, innovation and economic models, which are independent of specific technological paradigms. Test 1 evaluates the ability of a dominant manufacturing paradigm to preserve a competitive advantage over the other paradigms against Porter's (1996) Model of Strategy. Test 2 evaluates the return on investment the three dominant manufacturing paradigms generate from the adoption of a generic manufacturing system innovation against Paap and Katz's (2004) Model of Dynamic Innovation. Test 3 evaluates the capability of the three dominant manufacturing paradigms to create value against Hines *et al*'s (2004) Model of Value Creation.

**6.4.1 Test method.**

Tests 1 and 2 perform comparative evaluation, which ranks the three dominant manufacturing paradigms relative to each other. The candidate observed throughout their evaluation of the three dominant manufacturing paradigms in Chapter 5 of this dissertation that a compendium of generic competitive advantages can be compiled. The candidate reasoned that the generic competitive advantages are common to all three dominant manufacturing paradigms, albeit varying in strength between the paradigms. The candidate believes that the compendium provides relevant criteria for comparative analysis. Furthermore, the candidate argues that within the context of an explore-exploit continuum for manufacturing, the compendium is generic to manufacturing *per se*. The candidate included their hypothesis of a dynamic waste threshold (**H2**) in the compendium, which allows the candidate's assertion that waste can be a competitive advantage in manufacturing to be tested. Tests 1 and 2 apply the compendium as the criteria for comparative evaluation, which tests hypotheses **H1** and **H2** explicitly and hypotheses **H2a**, **H2b** and **H2c** implicitly. Test 3 is also a comparative analysis but applies the compendium implicitly and not explicitly. Table 29 shows the compendium.

*Table 29: Compendium of generic competitive advantages in manufacturing.*
*Source: Candidate's design.*

| GENERIC COMPETITIVE ADVANTAGE | |
|---|---|
| 1. WASTE THRESHOLD **(H2)**. | Ability to tolerate and leverage waste. |
| 2. STANDARDISATION. | Ability to standardise product, processes and competencies. |
| 3. PRODUCT AFFORDABILITY. | Ability to deliver cheapest product to mainstream market. |
| 4. PRODUCT DESIGN FLEXIBILITY. | Ability to change design/specification of products in full[89] production. |
| 5. KNOWLEDGE. | Ability to leverage producer's product/process knowledge and consumer's product knowledge/experience. |
| 6. PRODUCT QUALITY/ RELIABILITY/PERFORMANCE. | Ability to deliver best practice products and consumer relationships. |
| 7. ABILITY TO PUSH TECHNOLOGY. | Ability to create new consumer needs. |
| 8. ABILITY TO PULL TECHNOLOGY. | Ability to satisfy established consumer needs. |
| 9. ABILITY TO LEVERAGE NOVELTY AND I.P. | Ability to generate and leverage novelty through intellectual capital, patents, trademark, brand, trade secrets *etc*. |
| 10. ABILITY TO CREATE NEW MARKET. | Ability to create new market at paradigm or industry levels[90]. |
| 11. ABILITY TO RAPIDLY GROW MARKET. | Ability to facilitate and accommodate rapid market growth and embed a paradigm in a market. |
| 12. VULNERABILITY TO EXTERNAL CHANGE. | Ability to survive and likelihood of occurrence of disruptive or significant paradigm shifts. |
| 13. COST AND SPEED OF RECONFIGURATION. | Ability to efficiently reconfigure plant, tooling, competencies, processes, schedules and capacity for products in full production. |
| 14. FREEDOM FROM DOMINANT DESIGN. | Ability to switch cheaply to new paradigms or influence significantly the paradigms in which producer already competes. |
| 15. PRODUCTION SCOPE. | Ability to produce multiple or new paradigms and variants/customisation of products already in full production. |
| 16. SPEED OF RADICAL INNOVATION TO MARKET. | Ability to deliver radical innovation first to market[91]. |
| 17. CAPITAL INVESTMENT. | Ability to leverage sunk cost through capital investment. |
| 18. CASH FLOW REGULARITY. | Ability to generate regular cash flow. |

[89] Full production implies order fulfilment.
[90] Ability to extend market implied in ability to pull technology, product quality/reliability/performance and cash flow regularity.
[91] Incremental capability implied in ability to pull technology, knowledge, waste threshold and product quality/reliability/performance.

## 6.4.2 Test 1: Preservation of competitive advantage.

This section evaluates the ability of a dominant manufacturing paradigm to preserve a competitive advantage over the other paradigms against Porter's (1996) Model of Strategy.

Porter (1996, pp. 61-62) explained that operational effectiveness *per se* is not a strategy and that an enterprise will outperform rivals only if establishes a difference that it can preserve. Here, the candidate tests the ability of each dominant manufacturing paradigm to preserve a competitive advantage over the other paradigms. Ranking comparatively the ability of each dominant manufacturing paradigm to exploit the generic competitive advantages defined in Table 29 as a strength allows trends to be mapped and an aggregate ranking for overall strength to be determined. The candidate contents that if the aggregate rankings for the dominant manufacturing paradigms are similar, then it could be argued that each paradigm represents the benchmark of operational effectiveness for its era. Moreover, the candidate argues that the essence of sustainable manufacturing does not rest in the superiority of manufacturing paradigms but in the ability to reconfigure manufacturing systems according to contextual conditions.

Table 30 shows the candidate's results for Test 1: Preservation of competitive advantage. There are two key results that can be reported. Firstly, the three dominant manufacturing paradigms are equal in their overall ability to preserve competitive advantages because their aggregate rankings are the same. Secondly, there are clear trends in the migration of competitive advantages between the three dominant manufacturing paradigms.

***Table 30: Relative strengths of the dominant manufacturing paradigms.***
***Source: Candidate's design.***

| GENERIC COMPETITIVE ADVANTAGE | RELATIVE STRENGTH | CRAFTSMANSHIP 1886-1913 | MASS PRODUCTION 1913-1955 | LEAN MANUFACTURING 1955-present |
|---|---|---|---|---|
| 1. WASTE THRESHOLD **(H2)**. | 3. High | 3 | | |
| | 2. Moderate | | 2 | |
| | 1. Low | | | 1 |
| 2. STANDARDISATION. | 3. High | | 3 | |
| | 2. Moderate | | | 2 |
| | 1. Low | 1 | | |
| 3. PRODUCT AFFORDABILITY. | 3. High | | | 3 |
| | 2. Moderate | | 2 | |
| | 1. Low | 1 | | |
| 4. PRODUCT DESIGN FLEXIBILITY. | 3. High | 3 | | |
| | 2. Moderate | | | 2 |
| | 1. Low | | 1 | |
| 5. KNOWLEDGE. | 3. High | | | 3 |
| | 2. Moderate | | 2 | |
| | 1. Low | 1 | | |
| 6. PRODUCT QUALITY/RELIABILITY / PERFORMANCE | 3. High | | | 3 |
| | 2. Moderate | | 2 | |
| | 1. Low | 1 | | |

| | | | | |
|---|---|---|---|---|
| 7. ABILITY TO PUSH TECHNOLOGY. | 3. High | 3 | | |
| | 2. Moderate | | 2 | |
| | 1. Low | | | 1 |
| 8. ABILITY TO PULL TECHNOLOGY. | 3. High | | | 3 |
| | 2. Moderate | | 2 | |
| | 1. Low | 1 | | |
| 9. ABILITY TO LEVERAGE NOVELTY AND I.P. | 3. High | 3 | | |
| | 2. Moderate | | 2 | |
| | 1. Low | | | 1 |
| 10. ABILITY TO CREATE NEW MARKET. | 3. High | 3 | | |
| | 2. Moderate | | 2 | |
| | 1. Low | | | 1 |
| 11. ABILITY TO RAPIDLY GROW MARKET. | 3. High | | 3 | |
| | 2. Moderate | | | 2 |
| | 1. Low | 1 | | |
| 12. VULNERABILITY TO EXTERNAL CHANGE | 3. High | | | 3 |
| | 2. Moderate | | 2 | |
| | 1. Low | 1 | | |
| 13. COST AND SPEED OF RECONFIGURATION. | 3. High | 3 | | |
| | 2. Moderate | | | 2 |
| | 1. Low | | 1 | |
| 14. FREEDOM FROM DOMINANT DESIGN. | 3. High | 3 | | |
| | 2. Moderate | | 2 | |
| | 1. Low | | | 1 |
| 15. PRODUCTION SCOPE. | 3. High | 3 | | |
| | 2. Moderate | | | 2 |
| | 1. Low | | 1 | |
| 16. SPEED OF RADICAL INNOVATION TO MARKET. | 3. High | 3 | | |
| | 2. Moderate | | 2 | |
| | 1. Low | | | 1 |
| 17. CAPITAL INVESTMENT. | 3. High | | 3 | |
| | 2. Moderate | | | 2 |
| | 1. Low | 1 | | |
| 18. CASH FLOW REGULARITY. | 3. High | | | 3 |
| | 2. Moderate | | 2 | |
| | 1. Low | 1 | | |
| **AGGREGATE RANKING FOR OVERALL STRENGTH** | | **36** | **36** | **36** |

### 6.4.3 Test 2: Return on investment.

This section evaluates the return on investment the three dominant manufacturing paradigms generate from the adoption of a generic manufacturing system innovation against Paap and Katz's (2004) Model of Dynamic Innovation.

Paap and Katz (2004) explained that technological innovation *per se* does not create value or a return on investment (ROI). According to Paap and Katz (2004, p. 17): "Generating a return on a technology investment requires both the ability of the technology to create a change and the change to create an impact on the targeted customer". Paap and Katz (2004) established a Model of Dynamic Innovation, where the adoption of an innovation depends upon the achievement of a minimum leverage threshold with prospective customers.

The significance of Paap and Katz's (2004) dynamic innovation model to this dissertation is that the candidate believes it can be adapted to reconcile the varying responses to a manufacturing systems innovation from the joint perspectives of producers and consumers.

**Drum vs. disc brakes.**

The candidate located an example within the automobile paradigm where there were differing responses to a technological innovation from producers and consumers, which affected the innovation's adoption. Drum and disc brakes were both invented[92] in 1902 (Quintessence, 2009. pp. 518-519). A question that requires resolution is why were inferior[93] performing drum brakes adopted before superior performing disc brakes? The candidate argues that Paap and Katz's (2004) model can be used to answer this question. *I.e.* disc brakes did not achieve sufficient leverage with early market consumers because they lacked experience in the performance differentiation between disc and drum brakes. The closest brake conceptualisation from the consumer's perspective was with horse-drawn wagons[94]. However, drum brakes were efficient to manufacture, which suited MP (Quintessence, 2009, p. 518). Here, drum brakes had high leverage with producers, which dominated the technology's adoption. A new market expectation was created after the introduction of disc brakes on several high-end vehicles in the 1960's (Quintessence, 2009, p. 518). Mainstream consumers could make an objective performance assessment of disc brakes because of decades of experience with drum brakes. Here, the consumer gained leverage rapidly through their expectations and demand, which provided incentive for producers to adapt to disc brake production on a large scale.

**Generic manufacturing system innovation.**

The candidate argues that Paap and Katz's (2004) model can be applied to innovations in manufacturing systems and in doing so it is possible achieve two outcomes. Firstly, the leverage for the manufacturing innovation from the producer's and consumer's perspectives can be compared. Secondly, the combined leverage of the innovation from producer and consumer can be used to compare the three dominant manufacturing paradigms. Here, the candidate believes that the generic competitive advantages defined in Table 29 represent generic manufacturing systems innovations.

[92] Disc brakes were patented by Lanchester. Drum brakes were invented by Renault (Quintessence, 2009. pp. 518-519).

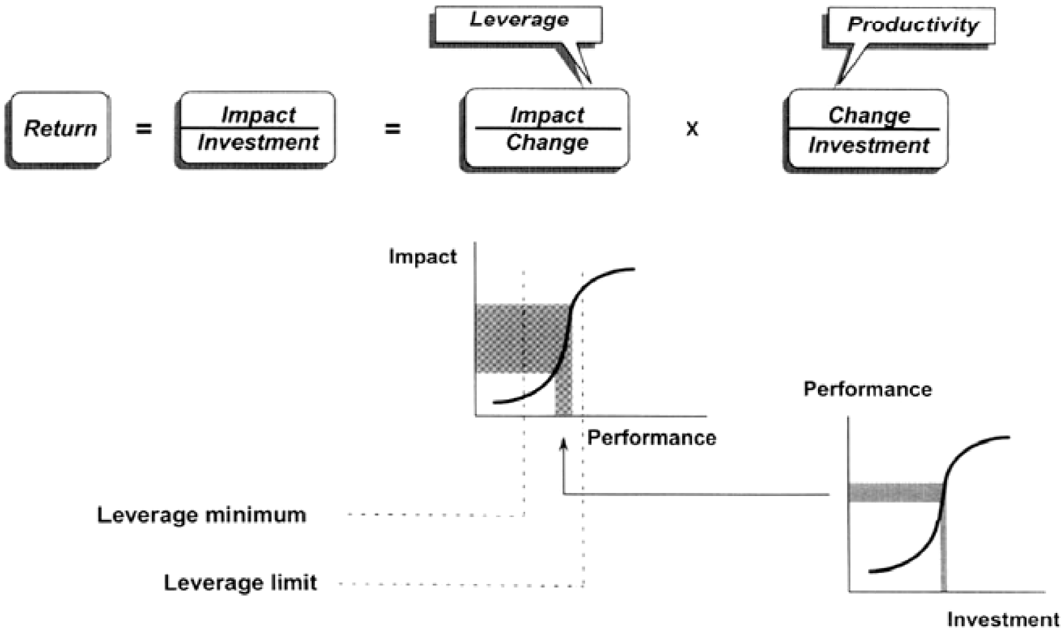
[93] Drum brakes are becoming increasingly prohibitive through safety regulations.

[94] Early automobile brake designs looked to the old paradigm of horse drawn carriages: levers with friction blocks applied directly to the wheels. The arrival of pneumatic tires resulted in an attempt to establish a "band brake" (friction band wrapped around a drum), which failed in preference to the superior drum concept (Quintessence, 2009, p. 502).

**Dynamic innovation model.**

Paap and Katz's (2004) model explains that innovation can incite change, which has the potential to provide ROI. The ability of an innovation to make change is its productivity. The extent to which the innovation is valued is its leverage. The ROI from an innovation is the impact achieved per investment made. Figure 10 explains Paap and Katz's model.

***Figure 10: Model of Dynamic Innovation.***
***Source:*** Paap and Katz (2004, p. 17).




- PRODUCTIVITY: extent to which investment in an innovation improves performance.
- LEVERAGE: extent to which performance improvement is perceived as having value.
- LEVERAGE MINIMUM: threshold where the innovation is first valued by a customer.
- LEVERAGE LIMIT: point where the innovation is no longer valued by the customer.

**Relative return on investment from the dominant manufacturing paradigms.**

The relative overall ROI from each dominant manufacturing paradigm for the adoption of a generic manufacturing systems innovation can be determined by ranking the innovation's productivity once a minimum leverage threshold has been achieved. The overall ROI achieved by a dominant manufacturing paradigm represents the ability of the paradigm to exploit the generic competitive advantage from the manufacturing systems innovation.

Table 31 shows the candidate's results for Test 2: Return on investment evaluation. There are two key results that can be reported. Firstly, the three dominant manufacturing paradigms are equal in their overall ability to generate a return on investment from manufacturing systems innovation because their aggregate rankings are the same. Secondly, there are clear trends in the migration of manufacturing systems innovation between the three dominant manufacturing paradigms.

*Table 31: Relative return on investment from the dominant manufacturing paradigms.*
*Source: Candidate's design.*

| **GENERIC COMPETITIVE ADVANTAGE** (manufacturing systems innovation). | **ROI** | | **CRAFTSMANSHIP** 1886-1913 | | **MASS PRODUCTION** 1913-1955 | | **LEAN MANUFACTURING** 1955-present | |
|---|---|---|---|---|---|---|---|---|
| | | | Internal customer perspective (producer) | External customer perspective (consumer) | Internal customer perspective (producer) | External customer perspective (consumer) | Internal customer perspective (producer) | External customer perspective (consumer) |
| 1. WASTE THRESHOLD **(H2)**. | Overall ROI | 3 high | **3** | | | | | |
| | | 2 some | | | **2** | | | |
| | | 1 minimal | | | | | **1** | |
| | Productivity | 3 high | √ | √ | √ | | | |
| | | 2 medium | | | | | | |
| | | 1 low | | | | | | |
| | Leverage | 3 high | √ | √ | | | | |
| | | 2 medium | | | √ | | | |
| | | 1 low | | | | | | |
| | Leverage limit | | X | X | √ | | | |
| | Leverage min. | | √ | √ | √ | X | X | X |
| 2. STANDARDISATION. | Overall ROI | 3 high | | | **3** | | | |
| | | 2 some | | | | | **2** | |
| | | 1 minimal | **1** | | | | | |
| | Productivity | 3 high | | | √ | | √ | |
| | | 2 medium | | | | | | |
| | | 1 low | | | | √ | | |
| | Leverage | 3 high | | | √ | | √ | |
| | | 2 medium | | | | | | |
| | | 1 low | | | | √ | | |
| | Leverage limit | | | | X | √ | X | |
| | Leverage min. | | X | X | √ | √ | √ | X |
| 3. PRODUCT AFFORDABILITY. | Overall ROI | 3 high | | | | | **3** | |
| | | 2 some | | | **2** | | | |
| | | 1 minimal | **1** | | | | | |
| | Productivity | 3 high | | | | √ | √ | √ |
| | | 2 medium | | | √ a | | | |
| | | 1 low | √ | √ | | | | |
| | Leverage | 3 high | | | √ | √ | √ | √ |
| | | 2 medium | | | | | | |
| | | 1 low | √ | √ | | | | |
| | Leverage limit | | √ | X | √ | X | √ | X |
| | Leverage min. | | √ | √ | √ | √ | √ | √ |
| 4. PRODUCT DESIGN FLEXIBILITY. | Overall ROI | 3 high | **3** | | | | | |
| | | 2 some | | | | | **2** | |
| | | 1 minimal | | | **1** | | | |
| | Productivity | 3 high | √ | √ d,e | | √ | | √ |
| | | 2 medium | | | | | √ | |
| | | 1 low | | | √ | | | |
| | Leverage | 3 high | √ | √ | | √ | | √ |
| | | 2 medium | | | | | √ | |
| | | 1 low | | | √ | | | |
| | Leverage limit | | X | X | √ | X | √ | X |
| | Leverage min. | | √ | √ | √ | √ | √ | √ |
| 5. KNOWLEDGE. | Overall ROI | 3 high | | | | | **3** | |
| | | 2 some | | | **2** | | | |
| | | 1 minimal | **1** | | | | | |
| | Productivity | 3 high | | √ e | | √ | √ | √ |
| | | 2 medium | | | √ | | | |
| | | 1 low | √ | | | | | |
| | Leverage | 3 high | | √ | | √ | √ | √ |
| | | 2 medium | | | √ b | | | |
| | | 1 low | √ | | | | | |
| | Leverage limit | 3 high | X | X | X | X | X | X |
| | Leverage min. | 2 some | √ | √ | √ | √ | √ | √ |
| 6. PRODUCT QUALITY/RELIABILITY/ PERFORMANCE | Overall ROI | 3 high | | | | | **3** | |
| | | 2 some | | | **2** | | | |
| | | 1 minimal | **1** | | | | | |
| | Productivity | 3 high | | √ d,e | | √ | √ | √ |
| | | 2 medium | | | √ c | | | |
| | | 1 low | √ | | | | | |
| | Leverage | 3 high | | √ | | √ | √ | √ |
| | | 2 medium | | | √ | | | |
| | | 1 low | √ | | | | | |
| | Leverage limit | | X | X | X | X | X | X |
| | Leverage min. | | √ | √ | √ | √ | √ | √ |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 7. ABILITY TO PUSH TECHNOLOGY. | Overall ROI | 3 high | 3 | | | | | |
| | | 2 some | | | 2 | | | |
| | | 1 minimal | | | | | 1 | |
| | Productivity | 3 high | √ | √[d] | | √ | | √ |
| | | 2 medium | | | √ | | | |
| | | 1 low | | | | | | |
| | Leverage | 3 high | √ | √ | | √ | | √ |
| | | 2 medium | | | √ | | | |
| | | 1 low | | | | | | |
| | Leverage limit | | X | X | √ | X | | X |
| | Leverage min. | | √ | √ | √ | √ | X | √ |
| 8. ABILITY TO PULL TECHNOLOGY. | Overall ROI | 3 high | | | | | 3 | |
| | | 2 some | | | 2 | | | |
| | | 1 minimal | 1 | | | | | |
| | Productivity | 3 high | | √[e] | | √ | √ | √ |
| | | 2 medium | | | | | | |
| | | 1 low | | | √ | | | |
| | Leverage | 3 high | | √ | | √ | √ | √ |
| | | 2 medium | | | | | | |
| | | 1 low | | | √ | | | |
| | Leverage limit | | | X | √ | X | X | X |
| | Leverage min. | | X | | √ | | √ | |
| 9. ABILITY TO LEVERAGE NOVELTY AND I.P. | Overall ROI | 3 high | 3 | | | | | |
| | | 2 some | | | 2 | | | |
| | | 1 minimal | | | | | 1 | |
| | Productivity | 3 high | √ | √[d] | | √ | | √ |
| | | 2 medium | | | √ | | | |
| | | 1 low | | | | | √[f] | |
| | Leverage | 3 high | √ | √ | | √ | | √ |
| | | 2 medium | | | √ | | | |
| | | 1 low | | | | | √ | |
| | Leverage limit | | X | X | X | X | X | X |
| | Leverage min. | | √ | √ | √ | √ | √ | √ |
| 10. ABILITY TO CREATE NEW MARKET. | Overall ROI | 3 high | 3 | | | | | |
| | | 2 some | | | 2 | | | |
| | | 1 minimal | | | | | 1 | |
| | Productivity | 3 high | √ | √[d] | | √ | | √ |
| | | 2 medium | | | √ | | | |
| | | 1 low | | | | | √ | |
| | Leverage | 3 high | √ | √ | | √ | | √ |
| | | 2 medium | | | √ | | | |
| | | 1 low | | | | | √[g] | |
| | Leverage limit | | X | X | X | X | X | X |
| | Leverage min. | | √ | √ | √ | √ | √ | √ |
| 11. ABILITY TO RAPIDLY GROW MARKET. | Overall ROI | 3 high | | | 3 | | | |
| | | 2 some | | | | | 2 | |
| | | 1 minimal | 1 | | | | | |
| | Productivity | 3 high | | √[i] | √ | √ | √ | √ |
| | | 2 medium | | | | | | |
| | | 1 low | √[h] | | | | | |
| | Leverage | 3 high | | √ | √ | √ | | √ |
| | | 2 medium | | | | | | |
| | | 1 low | √ | | | | √[j] | |
| | Leverage limit | | X | X | X | X | X | X |
| | Leverage min. | | √ | √ | √ | √ | √ | √ |
| 12. VULNERABILITY TO EXTERNAL CHANGE. | Overall ROI | 3 high | | | | | 3 | |
| | | 2 some | | | 2 | | | |
| | | 1 minimal | 1 | | | | | |
| | Productivity | 3 high | | | | | √[l] | |
| | | 2 medium | | | √[l] | | | √ |
| | | 1 low | √[l] | √[o] | | √[r] | | |
| | Leverage | 3 high | | | | | √ | |
| | | 2 medium | | | √ | | | √ |
| | | 1 low | √ | √ | | √ | | |
| | Leverage limit | | √[m] | √[n] | √[p] | √[q] | X[s] | X[t] |
| | Leverage min. | | √[k] | √[k] | √[k] | √[k] | √[k] | √[k] |
| 13. COST AND SPEED OF RECONFIGURATION. | Overall ROI | 3 high | 3 | | | | | |
| | | 2 some | | | | | 2 | |
| | | 1 minimal | | | 1 | | | |
| | Productivity | 3 high | √ | √[e] | | √ | √ | √ |
| | | 2 medium | | | | | | |
| | | 1 low | | | √ | | | |
| | Leverage | 3 high | √ | √ | | √ | | √ |
| | | 2 medium | | | | | √[u] | |
| | | 1 low | | | √ | | | |
| | Leverage limit | | X | X | √ | X | √ | X |
| | Leverage min. | | √ | √ | √ | √ | √ | √ |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 14. FREEDOM FROM DOMINANT DESIGN. | Overall ROI | 3 high | 3 | | | | | |
| | | 2 some | | | 2 | | | |
| | | 1 minimal | | | | | 1 | |
| | Productivity | 3 high | √ | √ d,e | | √ d,e | | √ d,e |
| | | 2 medium | | | | | | |
| | | 1 low | | | √ | | | |
| | Leverage | 3 high | √ | √ | | √ | | √ |
| | | 2 medium | | | | | | |
| | | 1 low | | | √ | | | |
| | Leverage limit | | X | X | √ | X | | X |
| | Leverage min. | | √ | √ | √ | √ | X | √ |
| 15. PRODUCTION SCOPE. | Overall ROI | 3 high | 3 | | | | | |
| | | 2 some | | | | | 2 | |
| | | 1 minimal | | | 1 | | | |
| | Productivity | 3 high | √ | √ e | | √ e | √ | √ e |
| | | 2 medium | | | | | | |
| | | 1 low | | | | | | |
| | Leverage | 3 high | √ | √ | | √ | | √ |
| | | 2 medium | | | | | √ u | |
| | | 1 low | | | | | | |
| | Leverage limit | | X | X | | X | √ | X |
| | Leverage min. | | √ | √ | X | √ | √ | √ |
| 16. SPEED OF RADICAL INNOVATION TO MARKET. | Overall ROI | 3 high | 3 | | | | | |
| | | 2 some | | | 2 | | | |
| | | 1 minimal | | | | | 1 | |
| | Productivity | 3 high | √ | √ d,e | √ | √ d,e | √ | √ d,e |
| | | 2 medium | | | | | | |
| | | 1 low | | | | | | |
| | Leverage | 3 high | √ | √ | | √ | | √ |
| | | 2 medium | | | √ | | | |
| | | 1 low | | | | | √ | |
| | Leverage limit | | X | X | √ | X | √ | X |
| | Leverage min. | | √ | √ | √ | √ | √ | √ |
| 17. CAPITAL INVESTMENT. | Overall ROI | 3 high | | | 3 | | | |
| | | 2 some | | | | | 2 | |
| | | 1 minimal | 1 | | | | | |
| | Productivity | 3 high | | √ d,e | √ | √ d,e | √ | √ d,e |
| | | 2 medium | | | | | | |
| | | 1 low | | | | | | |
| | Leverage | 3 high | | √ | √ | √ | | √ |
| | | 2 medium | | | | | √ v | |
| | | 1 low | | | | | | |
| | Leverage limit | | | X | X | X | √ | X |
| | Leverage min. | | X | √ | √ | √ | √ | √ |
| 18. CASH FLOW REGULARITY. | Overall ROI | 3 high | | | | | 3 | |
| | | 2 some | | | 2 | | | |
| | | 1 minimal | 1 | | | | | |
| | Productivity | 3 high | | | | | √ | |
| | | 2 medium | | | √ | | | |
| | | 1 low | √ | | | | | |
| | Leverage | 3 high | | | | | √ | |
| | | 2 medium | | | √ | | | |
| | | 1 low | √ | | | | | |
| | Leverage limit | | X | | | | | |
| | Leverage min. | | √ | X | | X | | X |
| **AGGREGATE RANKING FOR OVERALL ROI** | | | **36** | | **36** | | **36** | |

## Table 31 footnotes.

a. MP is less productive than LM because of inventory waste.
b. Product improvement has less focus in MP than LM.
c. The focus in MP is cost because the early majority consumers have not formed fully their quality/reliability/performance criteria.
d. Assumes consumers are receptive to new ideas but may not purchase necessarily.
e. Assumes consumers always want their needs met.
f. Late entrants compete in an environment where overall novelty for a paradigm is fading and intellectual property generation tends to continuous incremental improvement.
g. Assumes concentration on existing paradigm.
h. Assumes focus is on market creation (not capacity capability).
i. Assumes consumers value network externality benefits.
j. Assumes conservative *jojo* attitude.
k. Based on fear of asset obsolescence.
l. Based on the need for risk mitigation strategies.
m. Assumes that pre-dominant design it pays to be mindful of architectural competition but not at expense of experimentation.
n. Based on innovator adopter novelty seeking propensity.
o. Based on innovator adopter risk taking propensity.
p. Limit required to justify high capital expenditure.

q. Limit required to justify purchase.
r. Based on early majority consumer confidence.
s. Based on fear of asset obsolescence in capital expenditure and human capital investment.
t. Based on late majority consumer fear of asset obsolescence in purchase decision.
u. Based on need to balance customisation with standardisation.
v. LM has a focus on human capital and low cost solutions.

### 6.4.4 Test 3: Value creation.

This section evaluates the capability of the three dominant manufacturing paradigms to create value against Hines *et al*'s (2004) Model of Value Creation.

#### 6.4.4 (a) LEAN MANUFACTURING MODEL OF VALUE CREATION.

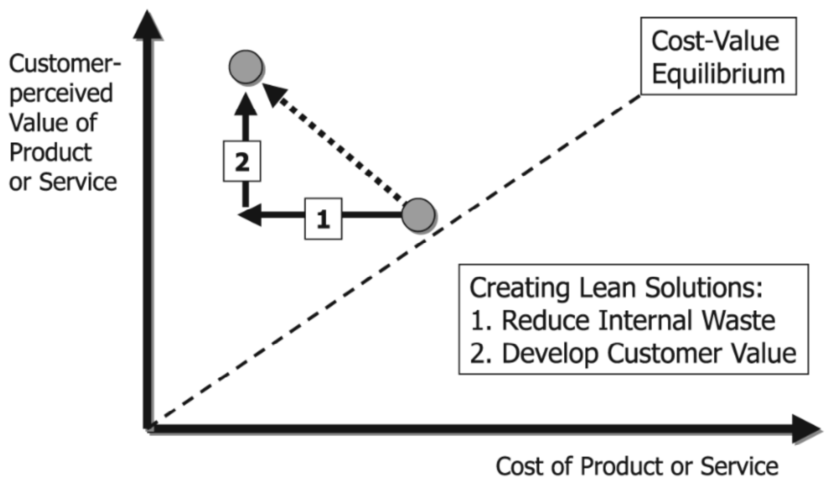
Hines *et al*. (2004) detailed a model of how value is created in LM. The candidate will show that Hines *et al*'s model is a metaphor for common economic theory and in doing so will apply the model to CR and MP.

**Lean enterprises and value streams.**

The concept of value is central to lean enterprises (Womack and Jones, 2003, p. 16). Lean enterprises strive to produce only that which adds value to the downstream customer (Monden, 1994, p. 2; Hines, 1996, p. 6; Hines *et al*., 2008, p. 4; Liker and Hoseus, 2008, pp. 43-44; Toyota Motor Corporation, Public Affairs Division, 2008, p. 9). The model lean enterprise comprises synergistic processes, which form streams of value-adding activities (Pettersen, 2009, pp. 134-136). According to Liker (2004, p. 191): "Toyota exists to add value to its customers".

LM has two methods for adding value to the customer. The first method fixes on waste reduction and the second method strives to create value. The relationship between the two LM value-adding methods is shown in Figure 11, which represents Hines *et al*. (2004) Model of Value Creation.

***Figure 11: Model of Value Creation.***
***Source:*** Hines *et al*. (2004, p. 997).



**Waste reduction as value-adding.**

Waste reduction is regarded to be value-adding in LM. The logic is that the customer does not want to pay for waste and therefore its elimination adds value to them. Garvin argues that whilst the product is not more valuable in price, its value from the customer's perspective is enhanced through affordability, reliability, performance, prestige, quality *etc.* (Garvin, 1987, pp. 107-108). The innateness of waste reduction is apparent intuitively within LM literature, which results typically in an aggressive approach towards waste elimination by new adopters of LM. Hines *et al*. found that new LM adopters show typically a bias in their value-adding approach towards waste reduction (Hines *et al.*, 2008, pp. 5-11). Here, Ortiz explains that the focus is on what the customer is not willing to pay for (Ortiz, 2006. p. 28). Hines *et al*. (2008) argue that in order to become a sustainable lean enterprise it is important to understand value-adding beyond waste elimination, which is centred upon the concept of customer perceived value.

**Customer perceived value.**

The concept of how a customer perceives value is important in lean value creation theory because it explains how value can be created in addition to waste elimination. Kamins *et al*. explain that a positive brand image can be achieved through the management of customer perceptions (Kamins *et al*., 2003, pp. 828-830).

***Articulated and latent needs.***

Value may be created by responding to a customer's latent needs, which is expressed through positive perceptions by the consumer towards a product or service. Value created from customer perceptions is different to satisfying specified needs, which are expressed as facts and figures (Garvin, 1984, p. 42; Hines *et al*., 2002, p. 7). *E.g.* value from latent needs may be reflected in positive quality and relationship perceptions by the consumer towards the producer and its products, which engender brand loyalty (Homburg *et al*., 2005, p. 84; Dube *et al*., 2008, p. 427). The consumer may not specify explicitly their need for greater performance in product feature "X" or enhanced service for "Y". However, the assumption and exploitation of the consumer's latent need by the producer may create a general positive perception in the consumer and become a source of value for the producer. Whilst the exploitation of general latent needs such as positive quality and relationship perceptions can add value, this approach can also be regarded as fundamentally a waste reduction method of value-adding. According to Hines *et al*., the exploitation of general latent needs is implied in the waste reduction logic that the customer does not want to pay for poor quality or relationships despite not specifying it explicitly (Hines *et al*., 2002, p. 7). Kano *et al*. explain that the satisfaction of a general latent need can be regarded as a response to a basic or expected need. The addition of value beyond the waste reduction method entails the stimulation of "excitement" needs in the consumer, which may please or delight them. Excitement needs can be regarded as discrete latent needs whose unfulfilment by the producer may not create a negative perception with the consumer, but ignorance by the producer may result in lost competitive advantage over rival producers (Kano *et al*., 1984, p. 39). The fulfilment of discrete latent needs entails additional products, services or features that may increase price but provide something that is valued by the customer (Porter, 1996, p. 62; Schilling, 2003, pp. 25-30). The stimulation of discrete latent needs in consumers creates value beyond the satisfaction of articulated, basic and expected needs. The selective stimulation of discrete latent needs can create a point of differentiation between producers. Sandberg explains that the satisfaction of the customer's articulated needs is reactive, whilst the development of discrete latent needs requires proactivity by the producer (Sandberg, 2007, p. 255). Table 32 shows the relationship of the LM value-adding methods to customer perceptions.

***Table 32: Relationship of lean manufacturing value-adding methods to customer perceptions. Source: Candidate's design based on*** Kano *et al*. (1984).

| LEAN VALUE-ADD METHOD | APPLICATION | KANO *et al*. (1984) EQUIVALENT |
|---|---|---|
| *1. Reduce internal waste.* | Ongoing satisfaction of articulated needs. | Performance needs (one-dimensional). |
| | Ongoing enhancement of general latent needs (as general positive perceptions in relationship and quality *etc*.). | Basic and expected needs. |
| *2. Develop customer value.* | Selective exploitation of discrete latent needs (as discrete positive perceptions of differentiation to rival offerings). | Excitement needs. |

***Continuous improvement.***

Customer perceptions migrate continually because the excitement needs of today become the expected needs of tomorrow (Kano *et al*., 1984). Moreover, technical characteristics may evolve to be secondary as consumption takes on a symbolic meaning in the recognition it gains and the messages it expresses[95] (Witt, 2010, p. 24). Value-adding in a lean enterprise accords with *kaizen* because it is ongoing. The ongoing satisfaction and enhancement of the consumer's articulated and general latent needs through waste elimination is a given. Moreover, so too must be the creation of value through the exploitation of the customer's discrete latent needs because points of differentiation for successful producers are soon emulated by rival producers.

***Short-term waste.***

Value creation may introduce waste in the short-term but can provide a platform for waste elimination and value creation in the future (Monden, 1994, p. 179; Liker, 2004, p. 280; Hines *et al.*, 2008, p. 49). Waste from value creation is often called *hiranga muda,* which results in inherently

[95] *E.g.* it can be argued that the hybrid Toyota Prius automobile's cost and technical 'green' performance is outweighed by the symbolic intent and message sent in purchasing one.

wasteful work procedures that must be tolerated temporarily[96] (Takeda, 2006, p. 150). *Hiranga muda* occurs typically during new product introduction and radical innovations because production stabilisation requires typically time, learning and future investment (Imai, 1986, p. 249).

**Cost-value equilibrium.**

The cost-value equilibrium (CVE) in Figure 11 is the point where cost equals perceived value from the customer's perspective. According to Hines *et al*. (2004, p. 997): the CVE represents "the situation whereby the product provides exactly as much value, which the customer is willing to pay for, as the product costs". The further a lean enterprise reduces costs (method 1) or adds perceived value (method 2) the more attractive a proposition it offers its customers. The area below the CVE represents an uncompetitive position (Hines *et al*., 2008).

### 6.4.4 (b) PARALLELS BETWEEN LEAN, ECONOMIC AND INNOVATION THEORIES.

The candidate observed that Hines *et al*'s (2004) Model of Value Creation has key criteria that are parallel with common economic theory. Furthermore, it has key criteria that are parallel with innovation theory. Here, the candidate argues that contextual conditions can be applied to Hines *et al*'s (2004) Model of Value Creation, which could be used to determine the relative value-adding performance of the three dominant manufacturing paradigms.

**Economic parallel.**

The candidate noted that the CVE is related directly to the economic concept of total utility. Total utility is the maximum amount of money that a consumer is willing to exchange for a product (Baumol and Blinder, 2005, p. 62).

***Utility.***

Utility is used by economists for the analysis of consumer purchase decisions when consumers are confronted with choice. Utility is founded on the concept that consumers will spend their income in way that maximises satisfaction or utility (Baumol and Blinder, 2005, p.61; Lee *et al*., 2008, p. 2962). Utility analysis centres on actual consumer behaviour rather than the consumer's cognitive processes, which provides a practical means for integrating psychological attitudes with the concept of money. Utility analysis provides a quantitative building block for understanding demand dynamics. The CVE relates to utility in two key ways. Firstly, for any given point in time, CVE and utility represent a purchase decision threshold. Secondly, CVE and utility are based on the consumer's

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[96] Ohno (1988, pp. 57-58) regarded waste from value creation as "non value adding work", which although must be performed under current circumstances is nevertheless waste and should be eliminated. Effectively, this is a temporary sub-category of waste between pure waste (obvious and eliminated immediately) and value adding work (wasteless).

willingness[97] to pay. Here, lean value creation theory aligns with economic theory because the consumer's behaviour towards a product is a net outcome from their purchasing decision, which reflects the satisfaction and utility derived from a product based on their perception of its value.

***Efficiency.***

Lean value creation theory is also related to the economic concept of efficiency. Economic efficiency is driven by waste reduction and technological advancement, which results in utility to the consumer as the net output. Efficiency improvements are achieved when an enterprise increases outputs without increasing inputs. Increased efficiency shifts the frontiers of technological knowledge and production possibilities (Baumol and Blinder, 2005, p. 31). The candidate argues that increased economic efficiency mirrors positive shifts in a CVE.

**Innovation parallel.**

The candidate observed that lean value creation theory mirrors Porter's explanation of strategic positioning by an enterprise within an established market. Porter argued that a productivity frontier exists within a market, which represents the state of best practice for its industry. Enterprises can either compete at the established productivity frontier through efficiency or manipulate a differentiating strategic position. Competition at the established productivity frontier through efficiency entails the improvement of a producer's cost position relative to its competitors. The manipulation of a differentiating strategic position entails the improvement of a producer's non-price value delivered to the consumer (Porter's, 1996, p. 62). Here, the candidate believes that Porter's (1996) model reflects Hine *et al*'s (2004) Model of Value Creation for three fundamental criteria. Firstly, Porter's relative cost position is the equivalent of cost in the lean value creation model. Secondly, Porter's non-price value is the equivalent of perceived value in the lean value creation model. Thirdly, Porter's productivity frontier is the equivalent of the CVE in the lean value creation model. Porter asserts that competition by the producer through the soles means of efficiency at the productivity frontier is not a strategic position *per se* because it will result ultimately in convergence with other producers and an exhaustion of improvement opportunities (Porter, 1996). Here, the candidate argues that a producer can differentiate itself through increasing the consumer's perceived value of the producer and its products through novelty.

[97] The candidate believes that key LM figures understood the concept of willingness to pay during the inflexion point for the automobile paradigm, which was characterised by a market that began to expect greater value for money. *E.g.* Feigenbaum (1956, p. 94): "Marketing evaluates the level of quality which customers want and for which they are willing to pay". Similarly, Toyota Motor Company founder Kiichiro Toyoda (Toyoda, n.d. cited in Ohno, 1988, p. 85): "In the end, prices must be competitive. A consumer automatically derives pleasure from buying something at a lower price". Here, Toyoda reflected the economic concept of consumer surplus, which states that if the price of a commodity is lower than what the consumer is willing to pay for it then the consumer achieves a net gain in utility from its purchase (Baumol and Blinder, 2005, p. 68).

*Table 33: Parallels between lean value creation theory and common economic and innovation theories.*
*Source: Candidate's design.*

| | LEAN VALUE CREATION THEORY | COMMON ECONOMIC THEORY | COMMON INNOVATION THEORY |
|---|---|---|---|
| **Purchaser's purchase decision point.** | **Cost-value equilibrium:** point where product or service cost equals perceived value from the customer's perspective (Hines *et al*, 2004, p.997). | **Total utility:** maximum amount of money a consumer is willing to exchange for a product or service (Baumol and Blinder, 2005, p. 62), which represents the greatest amount of satisfaction achieved (Baumol and Blinder, 2005, p. 61). | **Productivity frontier:** state of best practice between producer's cost and non-price buyer value delivered (Porter, 1996, p. 62). **Steady-state (Toyota):** "Doing what we do, but better (best practice)" (Bessant *et al*., 2005, p. 1366). |
| **Manufacturer's competitive market position.** | **Attractive proposition:** position where either or both value-adding methods have shifted in a positive direction away from the cost-value equilibrium (Hines *et al*, 2004, p.997). | **Increased efficiency:** whereby an enterprise produces more output without increasing inputs, by moving beyond the current frontiers of technological knowledge and production possibilities (Baumol and Blinder, 2005, p. 31). | **Strategic difference:** positive return on investment from innovation through disruption of steady-state (Paap and Katz, 2004, p. 16), which achieves competitive advantage over competitors through cost leadership, differentiation or focus (Porter 1980 cited in Tidd *et al*., 2005, p. 120; Porter 1985 cited in Porter, 1996, p. 67). |
| **Purchaser.** | **Customer.** (Hines *et al*., 2004). | **Consumer.** (*e.g.* Dacko *et al*., 2008). | **Adopter.** (*e.g.* Rogers, 1962 cited in Schilling, 2005, p. 46). |
| **Manufacturer.** | **Supplier.** (Hines *et al*., 2004). | **Producer.** (*e.g.* Dacko *et al*., 2008). | **Innovator.** (*e.g.* Killen, 2005b). |

**Dynamic equilibrium.**

Lean value theory is consistent with common economic and innovation theories in that CVEs are dynamic. A positive shift in a CVE results in an enhanced proposition from its producer, which shifts overall market demand and establishes a new CVE for its industry. Here, the candidate argues that the overall CVE for an industry represents the aggregate of the CVE's for its individual producers. Furthermore, whilst an individual producer may influence its market, the candidate argues that common economic and innovation trends pervade, which determine ultimately the outcome of aggregate CVEs.

### 6.4.4 (c) FRAMEWORK OF TRENDS FOR THE AUTOMOBILE'S COST-VALUE EQUILIBRIUM.

The candidate develops a framework in this section of the trends for the automobile paradigm's CVE. The candidate expects to show that there is systematic migration in the innovation strategy for the three dominant manufacturing paradigms, which reflects the CVE zone they compete in.

**Economic and technological aggregation.**

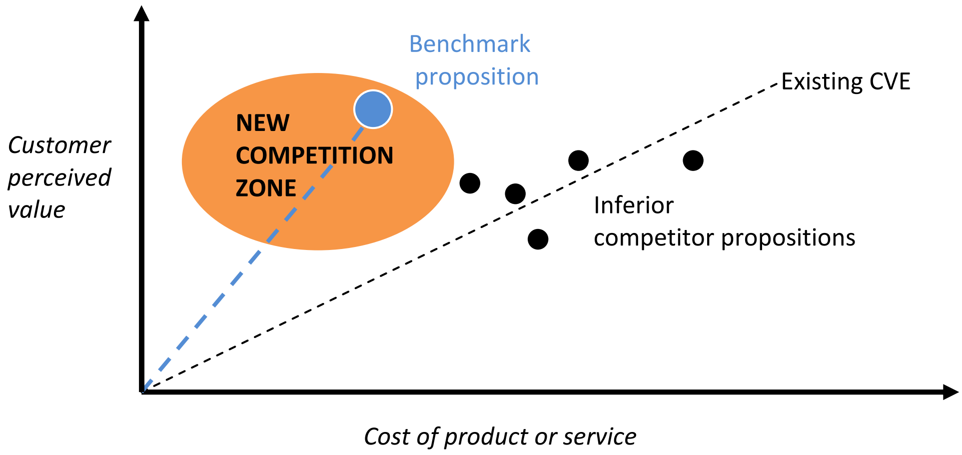
The market demand for a product is the aggregation of the demand curves for its individual consumers. Similarly, the market supply of a product is the aggregation of supply curves for its individual producers (Baumol and Blinder, 2005, Part II). The market can be regarded as system where individual consumers and producers act in their own interests and allocate resources according to free will (Baumol and Blinder, 2005, p. 750). A market system is characterised by producers manipulating their individual supply curves in order to change consumer demand. Here, the candidate argues that the manipulation of economic supply curves by suppliers is parallel to their manipulation of CVE's. Accordingly, for any given technological paradigm, individual producers have an aggregate CVE that comprises the unique CVE's for each variant and option offered for that paradigm by the producer. The aggregate CVE for any given technological paradigm at industry level is in turn the total aggregation of all its producers aggregate CVEs for that paradigm. Furthermore, the candidate argues that the technological trajectory for any given technological paradigm is an aggregation its technological trajectories at sub-paradigm levels. The candidate draws an analogy to Porter's (1996, p. 62) productivity frontier where the trajectory of a technological paradigm can be regarded as "the sum of all existing best practices at any given time".

The candidate has argued that the aggregate supply and demand curves for a product in economic theory are parallel to the aggregate CVE and trajectory for a technological paradigm. Here, the candidate presents four assertions about CVE's, which form the framework that will be used in this dissertation to evaluate the value-adding performance of the three dominant manufacturing paradigms.

**Candidate assertion 1: Benchmark propositions.**

The candidate asserts that positive movement away from an existing CVE by a producer results in a more attractive proposition to the consumer, which creates a more competitive position for its producer. The leading proposition shifts the industry benchmark within the market system and in doing so defines a new CVE and competition zone. Figure 12 illustrates the candidate's assertion.

*Figure 12: Benchmark propositions in Cost-Value Equilibrium.*
*Source: Candidate's design.*




**Candidate assertion 2: Diminishing total utility and opportunity cost.**

The candidate asserts that the total utility derived by the consumer from the purchase of a technological paradigm diminishes as the paradigm matures. Correspondingly, the consumer's opportunity cost diminishes. Diminishing total utility and opportunity cost for the consumer are correlated to falling purchase cost and fading product novelty.

**Product novelty and cost.**

Grebel showed that the technology-push phase of a technological trajectory does not follow necessarily normal laws of economic utility and that normal market mechanisms are absent effectively (Grebel, 2009). Chapter 4 of this dissertation explained that the customer-pull phase of a technological trajectory is characterised by a commodity market, which operates under normal selection mechanisms. Here, the candidate argues that commodity markets can be regarded to be elastic, where producers compete for market share of a normal good. Elastic markets are those where consumers are sensitive to price changes and can switch readily between producers (Baumol and Blinder, 2005, p. 87). Conversely, the candidate argues that a technology-push market is inelastic because innovator adopters are insensitive to price. Furthermore, that the mainstream consumers have different motivations behind their purchase decisions than innovator adopter consumers. The candidate believes that a question that requires resolution in lean value creation theory is how can the total utility or satisfaction gained from the opposing perspectives of mainstream and innovator adopters be reconciled. Here, both consumer groups are willing to pay for a product albeit with different reasons and outcomes. *I.e.* how can the willingness to pay of 1886 and 2011 automobile consumers be compared?

Franke *et al.* explain that the utility derived by innovator adopters is founded on **hedonic** needs whilst the utility derived by mainstream adopters is founded on **utilitarian** needs. Hedonic needs are novelty driven whilst utilitarian needs are driven by practicality (Franke *et al*., 2009). Novel products suffer a general degradation in attractiveness and perceived value over time as they become more affordable and proliferate (Gautam and Singh, 2008, p. 316-318). Furthermore, as the product's positive emotional effects from novelty fade there is general increase in the cognition of performance shortfalls, which has the effect of enhancing expectations (Homburg *et al*., 2006, pp. 28-29). Here, the candidate argues that willingness to pay and total utility derived is moderated by fading novelty and falling product cost. Moreover, that falling product costs from normal producer efficiency improvements consume increasingly a smaller fraction of the consumer's income, which results in diminishing opportunity cost in consumer purchasing decisions. The candidate believes that willingness to pay from the opposing perspectives of mainstream and innovator adopter consumers can be reconciled through their relative purchase decision dynamics. Here, the candidate argues that the innovator adopter achieves higher total utility than the mainstream adopter because they are willing to pay relatively more. The innovator adopter has relatively higher product and opportunity costs than the mainstream adopter, which is characterised by novelty seeking and low performance expectations in an inelastic market. Conversely, the mainstream adopter has relatively lower product and opportunity costs than the innovator adopter, which are couched in utilitarian needs and high performance expectations in an elastic market.

The candidate argues that there is an overall trend of diminishing total[98] utility derived by the consumer as a technological paradigm matures. Diminishing total utility is consistent with the relative purchase decision dynamics of the adopter categories, which are characterised by falling product costs from normal producer efficiency improvement, diminishing consumer opportunity costs, fading product novelty and enhanced consumer performance expectations. Table 34 summarises the candidate's argument. The candidate has based Table 34 on the trends for the time discounted cost of an average automobile, its typical consumer performance expectations and their perceptions of novelty towards it.

[98] The candidate believes that the trend in marginal utility is consistent with the argued trend for total utility. Marginal utility is the addition to total utility from the consumption of one more unit of a product. The law of diminishing marginal utility states that the more of a product the consumer purchases the less marginal utility an additional unit contributes to overall total utility or satisfaction. (Baumol and Blinder, 2005, p. 62). Marginal utility to the consumer follows product cost where the product's market price and consumer's marginal utility rise as the product becomes scarcer (Baumol and Blinder, 2005, p. 70).

*Table 34: Relative purchase decision dynamics of adopter categories.*
*Source: Candidate's design.*

| | **CRAFTSMANSHIP ERA** 1886-1913 | | **MASS PRODUCTION ERA** 1913-1955 | | **LEAN MANUFACTURING ERA** 1955 to present | |
|---|---|---|---|---|---|---|
| Adopter category. | Innovators. | | Early adopters – early majority. | | Late majority – laggards. | |
| | **HEDONIC** (scarce good) | | | | | **UTILITARIAN** (mainstream commodity) |
| **Purchase decision dynamics.** | **Relative total utility.** | **Relative opportunity cost.** | **Relative total utility** | **Relative opportunity cost.** | **Relative total utility** | **Relative opportunity cost.** |
| High income earner. | High | High | Moderate | Moderate | Low | Low |
| Middle income earner. | *N/A* | *Prohibitive* | High | High | Moderate | Moderate |
| Low income earner. | *N/A* | *Prohibitive* | *N/A* | *Prohibitive* | High | High |
| **Relative novelty and product cost.** | | | | | | |
| **Relative performance expectations.** | | | | | | |

**Candidate assertion 3: Diminishing perceived value and cost-value equilibrium contraction.**

The candidate asserts that there is an overall trend of contraction for a technological paradigm's CVE as it matures, which is characterised by diminishing perceived value.

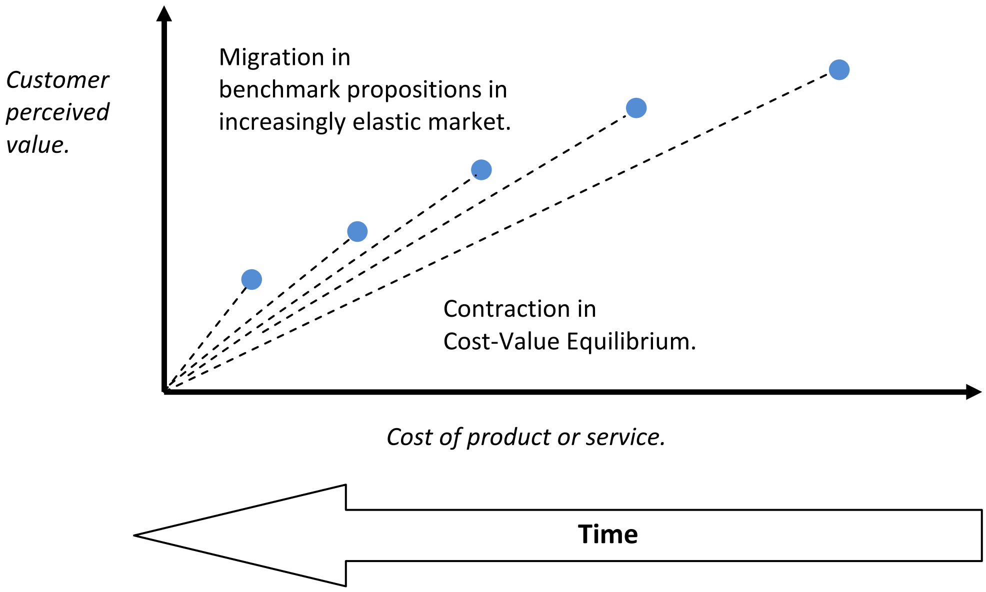
**Diminishing perceived value.**

The candidate argued that there is an overall trend of diminishing total utility derived by the consumer as a technological paradigm matures. Here, the candidate argues that the change in a technological paradigm's CVE over time can be regarded to be a function of its total utility to the consumer.

$$\frac{\Delta\, CVE}{\Delta\, Time} = f\,(\text{total utility})$$

An overall trend of diminishing total utility derived by the consumer implies that perceived value in lean value creation theory must also follow an overall downward trend. The total utility derived by the consumer reflects a consumers' willingness to pay based on product cost and perceived value. A technological paradigm's CVE must therefore follow an overall downward trend as it matures because product cost and total utility derived by the consumer follow overall downward trends. Figure 13 illustrates the argued trend of contraction.

*Figure 13: Contraction of a technological paradigm's Cost-Value Equilibrium over time. Source: Candidate's design.*




**Candidate assertion 4: Systematic migration in dominant innovation strategy.**

The candidate asserts that as a technological paradigm matures there is systematic migration in the competitive zones where producers compete and the dominant innovation strategy they employ.

**Steepening cost-value equilibrium slope.**

The contraction trend shown in Figure 13 means that the slope of a technological paradigm's CVE steepens as the paradigm matures. Here, the candidate argues that a CVE's slope represents the relative potential of one value-adding method over the other to add value to the consumer.

$$\frac{\Delta \textit{ Perceived value}}{\Delta \textit{ Cost}} = \textit{slope} = \textit{relative potential of one value-adding method over the other.}$$

The candidate argues further that the competition zone in which a producer competes and the potential of one value-adding method over the other indicates the value-add focus that should be employed in order to maximise value-adding to the consumer. Here, the candidate contends that the three dominant manufacturing paradigms are consistent with the change in value-add focus that should be employed in order to maximise value-adding to the consumer during the maturation of the automobile paradigm.

$$\frac{\Delta \textit{ Competition zone}}{\Delta \textit{ Time}} = \textit{change in value-add focus over time.}$$

### 6.4.4 (d) COST-VALUE EQUILIBRIUM ANALYSIS OF THE AUTOMOBILE PARADIGM.

The candidate's assertions in the framework of trends for the automobile's CVE can be tested by the implicit evaluation of the generic competitive advantages defined in Table 29 against Hines *et als*' (2004) Model of Value Creation.

**Cost-value equilibrium of the Craftsmanship era.**

The CR era represented an inelastic market that signified the birth of an industry. The barriers to participation for manufacturers were low, which resulted in a market that offered bountiful versions of a novel product (Montobbio, 2002, p. 390). The industry's aggregate CVE comprised the numerous CVE's of individual producers, which were characterised by high cost and high perceived value. Innovator adopter consumers were attracted to the newness of the technology and were resolved to purchase it (Lee *et al*., 2008, p. 2967). The novel automobile provided sensory arousal (Witt, 2010, p. 18), emotional and symbolic meaning (Dell'Era *et al*., 2010, p. 13) and conveyed social prestige that was consistent with the innovator adopter's self-image (del Rio *et al*., 2001, p. 412; Witt, 2010, p. 18).

CR automobile producers provided a product that represented the highest threshold of the consumer's willingness to pay. The candidate argues that CR production represents the limit of perceived value that can be generated by a new paradigm. Furthermore, whilst CR producers can strive to improve the novelty of a new paradigm their greatest value-add potential to consumers rests in cost reduction and improved performance, which results in diminishing consumer opportunity cost.

**Cost-value equilibrium of the Mass Production era.**

Ford's MP resulted in the cost of automobile ownership falling low enough to attract a new early majority adopter category. The Model T's price was $825[99] U.S. when it was launched in 1908 and annual sales exceeded 10,000 units (Smith, 2009, p. 50). The Model T's price fell to $575 U.S. when Ford's first production conveyor began operating in 1913 (Smith, 2009, p. 50). The Model T's price fell eventually to $290 U.S. in 1927 at which time at total of 15,000,000 units had been sold. The Model T's fall in price between 1908 and 1927 represented a reduction in manufacturing time from 728 to 93 minutes (Mika, 2006, p. 1). The Model T provided a product with "price democracy" (Gelber, 2008 cited in Luger, 2009, p. 582), which fulfilled Ford's vision of a "universal car" for the masses (Blanke, 2009, p. 954). The mass replication of a dominant design achieved economies of scale that resulted in rapid and attractive market growth (Montobbio, 2002, p. 390). More mass producers[100] followed in the wake of Ford's manufacturing system innovation, which resulted in the emergence of market elasticity. Choice from the consumer's perspective had shifted fundamentally

[99] Costs cited are actual figures from the era. The Model T's cost reduction is more dramatic when the time value of money (net present value) is considered.

[100] Major mass producers in U.S.A. were the "big 3" (Ford, Chrysler and GM) (Goldsborough, 1994, p. 38).

from bountiful versions of a novel product to reduced dramatically variants of a standardised design. The industry's aggregate CVE comprised the limited CVE's of individual producers, which were characterised by reduced dramatically cost and diminished perceived value. Diminished opportunity cost and enhanced performance eased dramatically the purchase decision dynamics for middle income early majority adopter consumers, which resulted in a general fading of novelty for all consumers and a significant fading of novelty for innovator adopter consumers.

Whilst the perceived value of the CR era could not be restored, MP producers continued to reduce cost but strove simultaneously to re-create a degree of novelty for high income earners through a reintroduction of choice[101].

**Cost-value equilibrium of the Lean Manufacturing era.**

The total global annual passenger car production at MP's peak in 1955 was approximately 10,000,000 units. Total annual global production had risen fivefold to approximately 50,000,000 units in 2007 when Toyota rose to dominance (Frost and Sullivan, 2008, p. 5). Toyota's capability to produce an efficient commodity that was reduced continually in price whilst having simultaneously enhanced performance and customisation potential had superior outcomes for mainstream consumers than MP's economies of scale (Lee *et al*., 2008, p. 2962). Global automotive production capacity in 2000 was only 68% utilised (CSM Worldwide 2008, cited in Commonwealth of Australia, 2008, p. 25). Toyota's customer-pull business model had emerged superior in an environment where supply exceeded demand (Ortt and van der Duin, 2008, p. 533). Moreover, Toyota's *kaizen* culture provided an effective tool for the ongoing reduction of production costs through the leveraging of accumulated and embedded learning (Balasubramanian and Lieberman, 2010, p. 391). The mainstream market had matured to become highly elastic, which was characterised by decreased entry of new producers and the exit of inefficient and non-adaptive producers (Porter, 1996, p. 62; Montobbio, 2002, p. 390). Here, the candidate argues that opportunity cost for the consumer was at its lowest point for all consumer categories, which resulted in high consumer purchasing power and discrimination between product offerings. High consumer purchasing power means that producers must manage carefully elasticity under the influence of powerful market selection mechanisms (Dacko *et al*., 2008, p. 460). Here, the candidate argues that producers had to find a means to counter firstly the fading of product novelty to its lowest overall point and secondly the diminishing opportunity to realise meaningful productivity improvements. The candidate argues further that the automobile industry's aggregate CVE in the LM era is contracting to its lowest consumer willingness to pay threshold with its steepest slope. Furthermore, the potential to value-add for the consumer

[101] Ford failed to read the growing market signals of lowered perceived value from a single offering until relatively late (Management Today, 2005, p. 19). GM challenged Ford by instigating a "prestige ladder" that could be climbed aspirationally. Five new brands were introduced that targeted specific market segments, which from lowest to highest prestige were: Chevrolet, Pontiac, Oldsmobile, Buick and Cadillac (Goldsborough, 1994, p. 38).

through increased perceived value is increasingly greater than the potential to decrease product cost. Whilst the overall perceived value of the automobile can not be recovered from previous eras, LM producers can take advantage of their mass customisation capability to inject a degree of novelty into their products. Gautam and Singh suggest that LM's mass customisation capability has the potential to enhance product attractiveness through the provision of tailored product variants and options (Gautam and Singh, 2008).

The candidate argues finally that the mainstream automobile industry is proliferating with numerous CVE's, which are characterised by increasingly customised offerings through the incremental manipulation of sub-paradigm product concepts. The mass aggregation of marginal CVE's allows LM producers to offset overall diminishing productivity improvement opportunities through the increased perceived value from novel consumer preference fits.

**6.4.4 (e) RESULTS FOR VALUE CREATION EVALUATION OF THE AUTOMOBILE PARADIGM.**

Figure 14 shows the competition zones where the three dominant manufacturing paradigms competed within the automobile paradigm's CVE. Table 35 summarises the characteristics of the CVE's for the dominant manufacturing paradigm's competition zones. Figure 15 symbolises the relationship between the automobile paradigm's S-curves for technological development and diffusion and the CVE's for the dominant manufacturing paradigms.

The result of Test 3: Value Creation shows that the exploitation of the generic competitive advantages defined in Table 29 for the creation of value throughout the automobile paradigm's technological evolution follow a systematic order that is consistent with the theory for a classical technological evolution and the candidate's hypotheses in this dissertation.

**Implications of results for the automobile paradigm.**

The candidate argues that the contraction of a technological paradigm's CVE as it matures implies that producers will encounter diminishing returns for their effort expended in cost reduction and the enhancement of perceived value. An investigation by Homburg *et al.* into the effect on a consumer's willingness to pay through decreased product cost and enhanced perceived value found that an inverse S-curve exists, which is characterised by increasing rapidly mainstream consumer insensitivity to producer improvement efforts as a technological paradigm matures. Whilst extremely high levels of customer satisfaction result in an acceleration of a mainstream consumer's willingness to pay, the benefit to the producer becomes prohibitive because of the high cost of its improvement efforts (Homburg *et al*., 2005). According to Clark (1985, p. 247): "In the limit, product and process change both decline in frequency and significance". Porter described aging markets as a "war of attrition", where continuous improvement opportunities become exhausted and competitors are reduced (Porter, 1996, p. 64). Lee found that competency enhancing enterprises adept in the marginal improvement of a consumer's total utility exhibit typically two possible outcomes as a technological paradigm reaches full maturity. The two possible outcomes are a virtuous cycle of knowledge accumulation and growth or a vicious cycle of depletion and decline (Lee, C-Y., 2010, p. 287). Here, the candidate argues that the emergence of *kakushin* in the Toyota literature and published discourse may signify virtuous growth. Moreover, that a sustained dominance of *kaizen* may result in a vicious cycle of depletion and decline.

*Figure 14: Competition zones in the automobile paradigm's Cost-Value Equilibrium. Source: Candidate's design.*

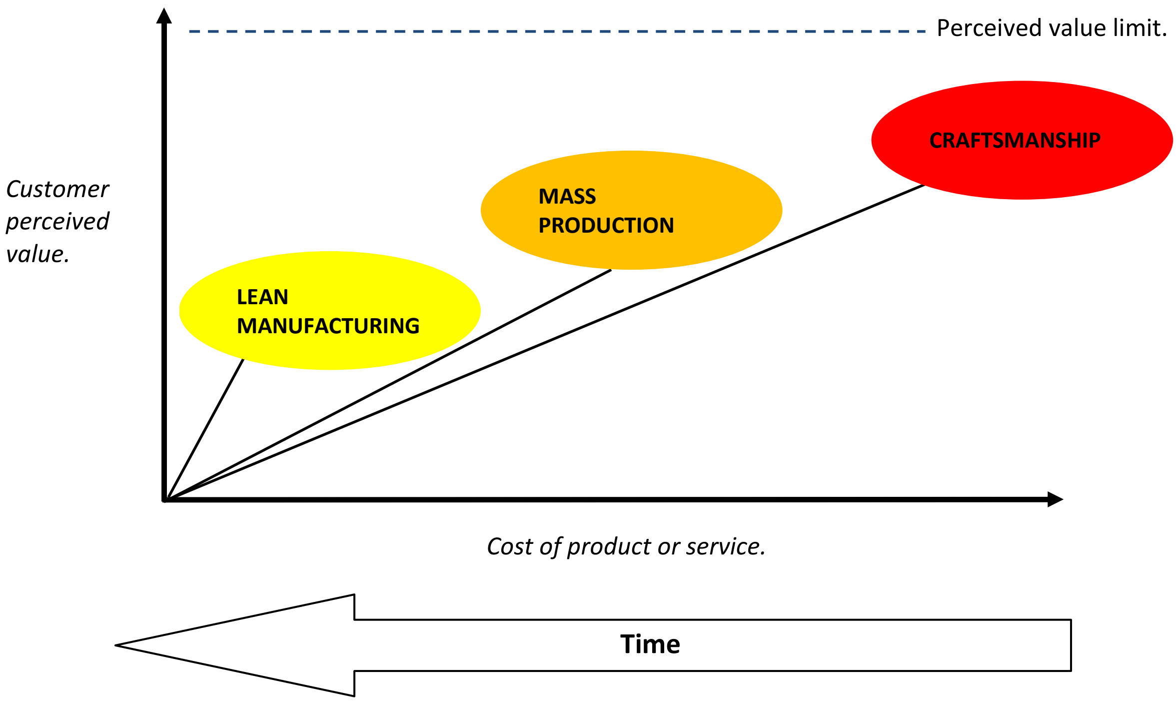
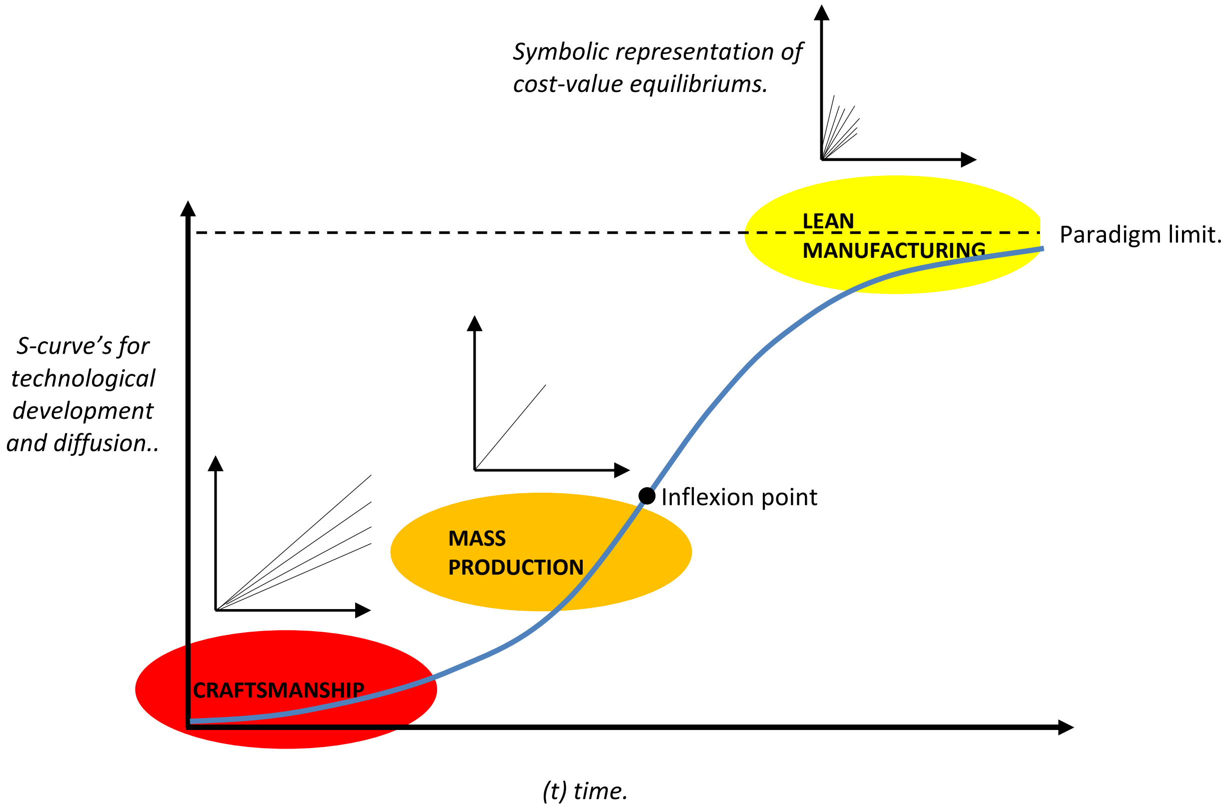



*Table 35: Characteristics of the competition zones in the automobile paradigm's Cost-Value Equilibrium. Source: Candidate's design.*

| | **CRAFTSMANSHIP ERA** 1886-1913 | **MASS PRODUCTION ERA** 1913-1955 | **LEAN MANUFACTURING ERA** 1955 to present |
|---|---|---|---|
| Slope. | Relatively flat. | Steepening. | Steep. |
| Competition zone. | Inelastic. | Emerging elasticity. | Elastic. |
| Relative consumer willingness to pay threshold. | High. | Moderate. | Low. |
| Relative potential to increase perceived value. | Low. | Moderate. | High. |
| Relative potential to decrease cost. | High. | Moderate. | Low. |
| Dominant innovation strategy. | Create cost-value equilibrium at paradigm level (and strive to organise manufacturing for dramatic cost reduction). | Lower costs dramatically at paradigm level (and strive to organise manufacturing for incremental cost reduction and production of novel variants). | Reduce costs incrementally and produce novel variants (and strive to organise manufacturing for mass customisation at sub-paradigm level). |

*Figure 15: Relationship of the automobile paradigm's S-curves to its CVE's.*
*Source: Candidate's design.*




| Adopter type. | Innovators/ technology enthusiasts. | Early adopters/ visionaries. | Early majority/ pragmatists. | Late majority/ conservatives. | Laggards/ sceptics. |
|---|---|---|---|---|---|
| **Dominant design.** | **Formation.** | | **Emergence.** | **Development.** | |
| **Producer time to market.** | **First mover.** | **Early follower.** | **Late entrant.** | | |
| **Market development.** | **Early.** | | **Mainstream.** | | |

**6.5 DISCUSSION OF RESULTS.**

The candidate believes that their evaluation of the three dominant manufacturing paradigms against existing strategic, innovation and economic models affirms hypotheses **H1** and **H2** explicitly and affirms sub-hypotheses **H2a, H2b** and **H2c** implicitly. A summary of the results is shown in Table 36.

***Table 36: Summary of results from the Candidate's hypotheses testing.***

| | **TEST 1: Preservation of competitive advantage** against Porter (1996) Model of Strategy (strategic evaluation). | **TEST 2: Return on investment** against Paap and Katz (2004) Model of Dynamic Innovation (innovation evaluation). | **TEST 3: Value creation** against Hines *et al.* (2004) Model of Value Creation (economic evaluation). |
|---|---|---|---|
| Hypothesis **H1**: Systemic migration. | Systematic order demonstrated (identical to Test 2).<br><br>Equal aggregate rankings for paradigms (identical to Test 2). | Systematic order demonstrated (identical to Test 1).<br><br>Equal aggregate rankings for paradigms (identical to Test 1). | Trends consistent with Test 1 and Test 2. |
| Hypothesis **H2**: Dynamic waste threshold. | Systematic order demonstrated (identical to Test 2). | Systematic order demonstrated (identical to Test 1). | Trends consistent with Test 1 and Test 2. |
| Sub-hypotheses: **H2a, H2b** and **H2c**. | Implied in testing of **H2**. | Implied in testing of **H2**. | Implied in testing of **H2**. |
| **COMMENT** | **H1** and **H2** tested explicitly. **H2a, H2b** and **H2c** tested implicitly. | **H1** and **H2** tested explicitly. **H2a, H2b** and **H2c** tested implicitly. | All hypotheses tested implicitly. |

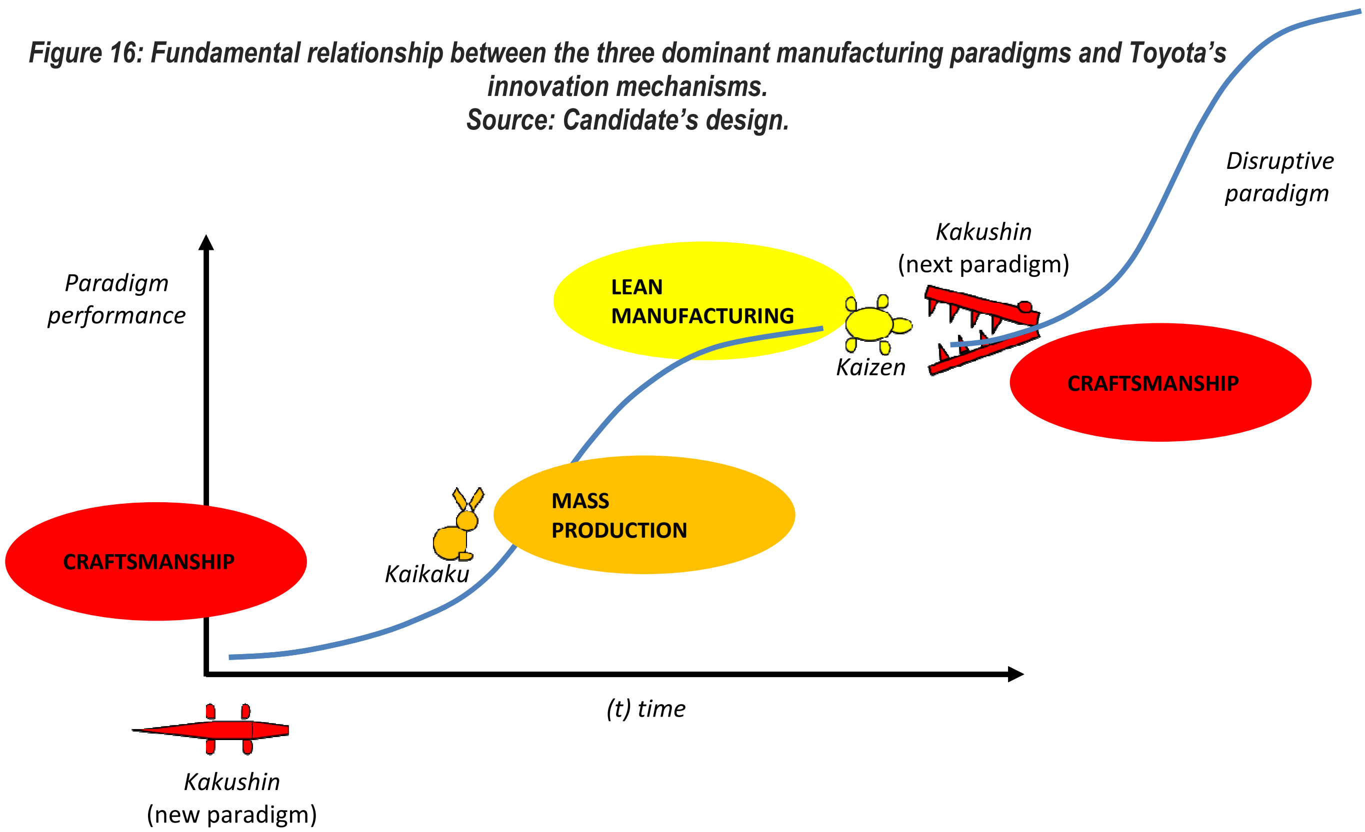
**Key outcomes from the results.**

The candidate submits that there are three key outcomes from the results. Firstly, there is a clear and systematic order in which the three dominant manufacturing paradigms evolve and the way they exploit the generic competitive advantages defined in Table 29. The systematic order in which the three dominant paradigms evolve can by symbolised CR-MP-LM – disruption - CR-MP-LM *etc*. The systematic order in which the three dominant manufacturing paradigms exploit generic competitive advantages follows in synchronicity with the evolution of the paradigms. Here, the candidate identified four sub-trends for how the strengths and weaknesses between the three dominant manufacturing paradigms migrated as the paradigms evolved. The sub-trends comprise two upward and two downward trends, which are characterised by CR starting at the extremes of the potential competitive advantage that can be derived from a generic competitive advantage. The candidate concluded a general trend where the weaknesses of any paradigm are strengthened by the following paradigm and the strengths of any paradigm are weakened by the following paradigm. Table 37 summarises the first key outcome. The second key outcome is that LM is equal in superiority to the other two dominant manufacturing paradigms according to the appropriate contextual conditions under which it operates. Here, the aggregate ranking of each dominant manufacturing paradigm is equal according to Tables 36 and 37. Thirdly, the contextual conditions under which Toyota's innovation mechanisms are facilitated reflect the three dominant manufacturing paradigms and are summarised: *kakushin* (CR), *kaikaku* (MP) and *kaizen* (LM). The fundamental relationship between the three dominant manufacturing paradigms and Toyota's innovation mechanisms are shown in Figure 16.

***Table 37: The systematic order between the three dominant manufacturing paradigms. Source: Candidate's design.***

| | **Technological paradigm 1** | | | | **Technological paradigm 2** | | | | **Technological paradigm 3** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **SYSTEMATIC PARADIGM ORDER** | CR | MP | LM | **DISRUPTION** | CR | MP | LM | **DISRUPTION** | CR | *Etc.* |
| **AGGREGATE RANKING** | Equal | Equal | Equal | | Equal | Equal | Equal | | Equal | *Etc.* |
| **SYSTEMATIC COMPETITIVE ADVANTAGE ORDER** (Based on relative competitive advantage derived). | | | | | | | | | | |
| Sub-trend 1. | **3** | **2** | **1** | | **3** | **2** | **1** | | **3** | *Etc.* |
| Sub-trend 2. | **3** | **1** | **2** | | **3** | **1** | **2** | | **3** | *Etc.* |
| Sub-trend 3. | **1** | **2** | **3** | | **1** | **2** | **3** | | **1** | *Etc.* |
| Sub-trend 4. | **1** | **3** | **2** | | **1** | **3** | **2** | | **1** | *Etc.* |

***Figure 16: Fundamental relationship between the three dominant manufacturing paradigms and Toyota's innovation mechanisms. Source: Candidate's design.***



## 6.6 SUMMARY

The candidate formed and tested hypotheses in this chapter for the relationship between the three dominant manufacturing paradigms of craftsmanship, mass production and lean manufacturing. The formation of the hypotheses was based on the evaluation of lean manufacturing in Chapter 5 against the theory in Chapter 4 of this dissertation.

Two primary hypotheses and three sub-hypotheses were formed by the candidate. The first primary hypothesis (**H1**) asserted that the three dominant manufacturing paradigms evolve in a systematic manner in which lean manufacturing is equal to the other two paradigms. The second primary hypothesis (**H2**) asserted that the three dominant manufacturing paradigms evolve around a dynamic waste threshold. **H2** was developed through three sub-hypotheses (**H2a**, **H2b** and **H2c**). **H2a** asserts that the dynamic waste threshold is a function of dominant design efficiency. **H2b** asserts that each dominant manufacturing paradigm has a unique waste profile around which its architecture is organised. **H2c** asserts that the net outcome from a dominant manufacturing paradigm's architecture is the facilitation of the dominant innovation object and mechanism that is appropriate for the contextual conditions the paradigm operates under.

The candidate tested the hypotheses against existing strategic, innovation and economic models, which constituted three tests. **Test 1** evaluated the ability of a dominant manufacturing paradigm to preserve a competitive advantage over the other paradigms against Porter's (1996) Model of Strategy. **Test 2** evaluated the return on investment the three dominant manufacturing paradigms generated from the adoption of a generic manufacturing system innovation against Paap and Katz's (2004) Model of Dynamic Innovation. **Test 3** evaluated the capability of the three dominant manufacturing paradigms to create value against Hines *et al*'s (2004) Model of Value Creation.

The candidate submits that their formation, testing and evaluation of hypotheses in this chapter achieved the outcome that was planned in the strategic argument mapped in Table 3 of this dissertation. There are four key parts to the outcome, which can be summarised as follows. Firstly, there is a clear and **systematic order** in which the three dominant manufacturing paradigms evolve and the way they exploit competitive advantages. Secondly, lean manufacturing is **equally superior** to the other two dominant manufacturing paradigms. Thirdly, the contextual conditions under which Toyota's innovation mechanisms are facilitated reflect the three dominant manufacturing paradigms and are summarised: *kakushin* (craftsmanship), *kaikaku* (mass production) and *kaizen* (lean manufacturing). Fourthly, the candidate concluded that the hypotheses are supported by the test results.

# CHAPTER 7
# THE PRODUCTIVITY, INNOVATOR'S AND PROACTIVITY DILEMMAS.

## 7.1 INTRODUCTION.

This chapter develops the theory for the transposition of the findings from the testing of hypotheses in Chapter 6 of this dissertation to processes other than manufacturing (quality management, supply chain management, product development *etc*.), according to the strategy in Table 3 of this dissertation. The state-of-the-art in the theory for the productivity dilemma, innovator's dilemma and ambidexterity is established. The theory for the candidate's concept of a proactivity dilemma is developed and the framework for the candidate's ambidexterity model is defined.

## 7.2 THE PRODUCTIVITY DILEMMA.

The "productivity dilemma" originated in Abernathy (1978) after research into the effects of exploitative processes on the long-term adaptability of firms in the automotive industry. Abernathy argued that a trade-off exists between efficiency and flexibility, whereby successful exploitation imposes increasingly rigidness throughout an enterprise that may present an obstacle to learning and innovation activity. The productivity dilemma is summarised by Adler *et al.* (2009, p. 99): "short term efficiency and long term adaptability are inherently incompatible".

## 7.3 THE INNOVATOR'S DILEMMA.

The "innovator's dilemma" originated in Christensen (1997) and aligns with the productivity dilemma. Christensen researched the effects of disruptive technologies on successful incumbent enterprises and found that exploitative enterprises are vulnerable to disruption from upstart newcomers. Christensen asserts that the routines an enterprise uses to facilitate the efficient satisfaction of mature customer needs increasingly foster rigidness and incremental innovation, which has the effect of dampening exploratory innovation activity and capability.

### 7.3.1 Exploration for the future vs. steady-state exploitation.

The productivity and innovator's dilemmas assert collectively that an enterprise's capabilities in exploitation may inadvertently engineer the enterprise's demise in the long-run. Here, a question that requires resolution is how can an enterprise manage exploration for the future whilst succeeding in steady-state exploitation? This question is the focus of ambidexterity research and is argued to go to the heart of innovation research (*e.g.* Tidd *et al*., 2005, p. 111; Magnusson *et al*., 2009, p. 3).

**Steady-state exploitation.**

Enterprises that focus on exploitation suffer typically from capability and knowledge obsolescence in the long-run (Levinthal and March, 1993, p. 105). Leading enterprises may fall victim to the "tyranny of success" (Paap and Katz, 2004, p. 14).

**Exploration for the future.**

Exploration is required to protect an enterprise against obsolescence (Bessant *et al.*, 2005). Exploratory innovation has the effect of disturbing the equilibrium of established markets and their producers (Antonelli, 2006, pp. 245-246). Whilst exploitative enterprises can suffer obsolescence, exploratory enterprises suffer typically a lack of returns for the capabilities and knowledge generated (Levinthal and March, 1993, p. 105).

The candidate submits that an **explore-exploit continuum** can be used for the transposition of the hypotheses in this dissertation for manufacturing to other core processes within a typical manufacturing enterprise.

### 7.3.2 Process behind the productivity and innovator's dilemmas.

The candidate believes that the productivity and innovator's dilemmas imply there is an ordered process that facilitates rigidness within an enterprise as it grows in exploitative capability. The candidate observed during the literature survey for this dissertation that the process of rigidness is characterised by several features, which are presented in the following sections.

**Culture.**

The creation of rules, identities and social templates can induce their evocation through the "logic of appropriateness" (March, 1994, p. 58). March explains that mature enterprises are characterised typically by entrenched identity constructs that influence decision making and impose moral obligations as a form of social control. The internalisation of a model identity that is appropriate to one's role constitutes a pre-packaged contract, which is incentivised by the opportunity to confirm one's competence through mutually shared rules of behaviour. The evocation of virtuous behaviour does not contradict the logic of appropriateness whereas antagonistic actions create emotional discord within the social system (March, 1994, Chapter 2). Enterprises with strong social constructs suffer frequently from the socially connected majority self-censoring unique and divergent knowledge from the socially isolated minority in order to preserve social cohesion (Thomas-Hunt *et al.*, 2003, pp. 473-475). A mature enterprise's social constructs become embedded in its reward and sanction systems (Lusk and Oliver, 1974, p. 556; March 1991, p. 73), behavioural codes, learning mechanisms and beliefs (Levinthal and March, 1993, pp. 108-109), shared mental models (Parkin, 1996, p. 140) and the social dynamics for the communication and organisation of innovation opportunities (van Looy *et al*., 2005, pp. 209-210). The identities that social constructs evoke frame and moderate decision making according to the preferred perception of the risk entailed and its anticipated consequences (Kahneman and Tversky, 1984). Lower-order decision making by individuals in successful exploitative enterprises can suffer from "looking up and around" for references, which may be driven by a fear of failure (Jackall, 1988, p. 31). Paradoxically, the process and social constraints required for the realisation of high levels of efficiency can result in automated activity streams, which may annul individual decisions but enhance efficiency (Mintzberg *et al*., 1990). Incremental innovation becomes more positive, predictable and easier to manage in an exploitative environment (March 1991, p. 85; Feller *et al*., 2006, p. 178; Dombrowski *et al*., 2007, p. 194). The stability that continuous incremental improvement affords can foster a culture of control and boundaries, which facilitates managerial trust in process outcomes (Khazanchi *et al*., 2007, p. 882). Moreover, stability promotes collective learning, competency enhancement and systematic accumulation of implemented rapidly innovation. March explains that a common negative consequence of a stable culture is the reinforcement of behavioural convergence with a subservient focus on short-term and safe incremental outcomes (March, 1991), which can impede an enterprise's development of new markets and increase its vulnerability to disruption (*e.g.* Winter, 2003, p. 994; Teece, 2007, p. 1328; Ellonen *et al*., 2009, p. 761).

**Organisational architecture.**

An exploitative culture that is coupled with tightly interrelated processes tends to dampen deviations to the status quo and impede anything but internally consistent change (March, 1994, p. 57; Benner and Tushman, 2002, p. 676; Janssen *et al*., 2004, pp. 131-132; Bessant *et al*., 2005, p. 1371; Adler *et al*., 2009, p. 101; Jayawarna and Holt, 2009, p. 775). High levels of rigidness can leave exploitative enterprises "variance hostile" (Benner and Tushman, 2003, p. 253). Culture can be regarded to reflect the mental and social architecture of an enterprise's intelligence (Levinthal and March, 1993). Correspondingly, an enterprise's culture is expressed through its processes and physical architecture. An enterprise's physical architecture embodies its structural capital and assets, which reflect the enterprise's intellectual capital, learning mechanisms, competencies and routines (Chang *et al.* 2008, p. 300; O'Reilly III and Tushman, 2008, p. 188). An enterprise's culture and physical architecture shape the political patterns that allow access to power and how it is exercised by individuals and groups (Fischer, 1990, pp. 277-279).

**Routinisation and codification.**

Routines constitute learned behaviour that is patterned and repetitious in order to achieve specific outcomes (Winter, 2003, p. 991). Routines are formed from the co-evolution of the processes for: tacit accumulation of past experience, knowledge articulation and codification (Zollo and Winter, 2002, p. 348). Routinised processes and codified knowledge represent storehouses of an enterprise's intellectual capital (Chang *et al*., 2008, p. 300), which form a platform for competency enhancement through the retention and replication of selected tacit knowledge for the facilitation of explicit behavioural entrenchment (Zollo and Winter, 2002, p. 344).

**Alliance stability and embeddedness.**

Exploitation is suited to non-turbulent environments where the competitive priorities of the manufacturing system are aligned with the potential to pursue competency enhancing best practice (Wang and Cao, 2008, pp. 359-360). Non-turbulent environments are characterised by a specific technological path and its mature market, which has well defined prices and market selection mechanisms with evolved production functions (Antonelli, 2006, p. 245). The inherent technological maturity of a non-turbulent environment provides the surety of a tested product design and proven organisational processes (Zollo and Winter, 2002, p. 349). Stable environments allow the formation of cohesive routines and capabilities throughout all echelons and functions of an enterprise (Peng *et al*., 2008, p. 743), which advance proficiency in process improvement, revenue enhancement, cost reduction and quality improvement (Drnevich and Kriauciunas, 2010). Environmental stability is characterised by post-dominant design embeddedness in enterprise alliances and positive consumption network externalities (Soh, 2010, p. 458). Stable environments are dominated typically by large enterprises that have strong financial performance with a powerful market presence and tend to overemphasise systematically exploitation at the expense of exploration (Uotila *et al*., 2009, p. 228). Enterprises that exploit systematically have typically knowledge creation and learning outcomes that are geared to continuous incremental improvement (Feller *et al*., 2006, p. 187) and supported by developed highly administrative capabilities for co-learning with alliance partners (Leiblein and Madsen 2009, p. 732). The exploitative capability of an enterprise is enhanced by leveraging the exploitation experience and knowledge of its partner organisations through an explicit and codified alliance (Hoang and Rothaermel, 2010, pp. 753-755). Consistency of knowledge management processes throughout the alliance enhances positively the identification of its constituent members with the alliance, which can promote compliance and participation in performance improvement initiatives (Ravishankar and Pan, 2008, pp. 231-232). Enhanced knowledge flows throughout the alliance and increased experience in appropriate knowledge search by its members enhances mutual absorptive capacity (Fosfuri and Tribo, 2008, p. 185). Absorptive capacity is “the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends” (Cohen and Levinthal, 1990, p. 128). Enhanced absorptive capacity by the alliance provides greater capability in exploitative innovation through synergistic collectivism rather than isolated individualism of its members (Leiblein and Madsen 2009, p. 730). Stable alliances have the greatest potential to exploit cooperative interaction with partner organisations (Malerba and Orsenigo 2010, p. 38). Exploitative interaction is effective because of a common innovation culture (Dombrowski *et al*., 2007, p. 200), shared competencies (March, 1991, p. 73) and growing absorptive capacity that focuses on customer-pull capability (Tu *et al*., 2006, p. 707; Murovec and Prodan, 2009, p. 849). The mutual trust that is embodied in information sharing promotes a psychologically safe environment to pursue the sanctioned direction in learning and knowledge creation (Choo *et al*., 2007, pp. 921-922), which engenders a willingness to codify knowledge (Renzl, 2008, p. 216). Increasing integration in the alliance's codification systems and their cultural appropriateness results in closer systemic adherence and reluctance in the circumvention of codified learning (Bendoly and Cotteleer, 2008, p. 37). High formalisation in the alliance's learning mechanisms and knowledge management benefit positively exploitative innovation (Jansen *et al*., 2006, p. 1670). However, the stability and embeddedness of the alliance's routines drives out exploratory innovation activity as a process management focus[102] is amplified increasingly by efficiency gains (Benner and Tushman, 2002, p. 676; Benner and Tushman, 2003, p. 253). Moreover, the heterogeneity required for the development of inimitable and dynamic innovation capabilities incurs growing management difficulty and costs, which makes increasingly its pursuit less attractive (Drnevich and Kriauciunas, 2010). The routines and tools used for exploitative innovation grow increasingly into obstacles to exploration (Magnusson *et al*., 2009, p. 2). The alliance's embeddedness, routinisation and acculturation presents increasing difficulty for changing and ending relationships between its members (Soh, 2010, p. 458), which presents a significant challenge for restructuring to an exploratory footing (Feller *et al*., 2006, p. 188). Further, the candidate's proactivity dilemma contends that restructuring to an exploratory footing is compounded by a tendency to retain and hire employees that are predisposed to proactivity in exploitation in a mature alliance. Here, the candidate argues that the paper by Parker and Collins suggests that employees may be predisposed psychologically and conditioned culturally for a conscientious fit with a fixed environment rather than attempting to scan for strategic opportunities, take control and incite change (Parker and Collins, 2010, pp. 655-656). Limited capacity for the restructuring of an enterprise's relationships with its alliance partners in an aging technological paradigm can result in diminishing returns and constrained future progress (Malerba and Orsenigo 2010, pp. 38-39).

**Lean manufacturing as an exemplar of exploitation.**

The candidate argues that Toyota's position as an exemplar of exploitation is consistent with the process behind the productivity and innovator's dilemmas. Osono *et al*. explain that Toyota embeds successful practices as new standards that are shared and imposed throughout its supply chain with the intent of precursing *kaizen*. Successful practices at Toyota are institutionalised by building them into daily routines because according to Osono *et al*. (2008, p. 84) non-capitalisation is: "lost organizational memory, resulting in wasteful reinvention of the wheel". Further, employee decisions are based on set of guidelines that are directed by the organisation (Osono *et al*., 2008, p. 173). Moreover, only employees who accept and fit with Toyota's values and culture and maintain actively

[102] A process management focus incites exploitation *per se* regardless of a firm's size or age (Benner and Tushman, 2002).

its corporate memory in their “heads and hands” find opportunities for promotion (Osono *et al*., 2008, p. 33). The candidate observes that Ohno’s vision of an autonomic industrial reflex is realised through an intense organisational culture, whose exploitative superiority lies not only in making routine and codifying “know how” but also “know why” (Zollo and Winter, 2002, p. 349).

### 7.4 THE PROACTIVITY DILEMMA.

The proactivity dilemma is a novel concept by the candidate that was introduced in Chapter 1 and developed partially in Chapter 6 of this dissertation. The proactivity dilemma asserted that exploratory behaviour is perceived increasingly non-proactive as proactivity in exploitation grows.

#### 7.4.1 Proactivity propensity of individuals.

The proactivity dilemma introduces an additional behavioural element to the productivity and innovator’s dilemmas. Successful exploration and exploitation require proactivity but have conflicting objectives. The proactivity dilemma implies that exploration and exploitation are executed through antagonistic interpretations of appropriate proactive behaviour. The candidate contends that exploration is proactive behaviour in a technology-push context whereas proactivity in exploitation within a technology-push context is detrimental behaviour. The converse applies in a customer-pull context. Appropriate proactivity is summarised in Table 38. The proactivity dilemma contributes to the theory of the productivity and innovator’s dilemmas by providing deeper insights into how exploration and exploitation are institutionalised within an enterprise from the perspective of **appropriate proactive behaviour**. Parker and Collins (2010, p. 656) found that individuals can be predisposed psychologically and emotionally to proactivity in one domain but not other domains. The candidate observed that the domains researched by Parker and Collins could be represented by the innovator-adopter continuum of personality traits developed by Kirton (1976), which the candidate related to exploration and exploitation in Chapter 2 of this dissertation.

The candidate’s concept of a proactivity dilemma asserts that enterprises with a proactivity focus in exploration or exploitation will be biased to employing and retaining individuals with complementary personality and behavioural traits, which has a reinforcing effect on the dominant proactivity focus. The proactivity dilemma is symbolised by the migration between Feigenbaum’s (1983) hidden plant and the candidate’s insidious plant, which was developed in Chapter 6 of this dissertation.

***Table 38: Appropriate proactivity.***
***Source: Candidate’s design.***

| Context. | TECHNOLOGY-PUSH | CUSTOMER-PULL |
|---|---|---|
| Desired outcome. | Exploration. | Exploitation. |
| Appropriate behaviour. | Proactivity in exploration. | Proactivity in exploitation. |
| Detrimental behaviour. | Proactivity in exploitation. | Proactivity in exploration. |

### 7.4.2 Proactivity propensity of executive management teams.

The candidate asserts that the concept of an inherent proactivity propensity in individuals can be extended to groups and teams. Here, the candidate focuses on executive management teams, which have the responsibility for setting an enterprise's strategic imperatives. Lower echelon teams and groups are discussed in proceeding chapters of this dissertation.

**Shared executive mental model.**

Executive management teams may develop a shared mental model or group mind, which influences how they perceive their competitive environment and strategic choices (Porac *et al*., 1989, pp. 397-399). Shared mental models are developed and reinforced through the re-enactment of decisions and behaviours that resulted in successful performance outcomes in the past (Osborne *et al*., 2001, p. 447). Porac *et al*. explain that shared executive mental models are common in commodity industries where producers and their suppliers enact decisions mutually. The strong economic selection mechanisms in a commodity market incite the market's incumbent producers to coordinate implicitly their competitive tactics towards the achievement of market stabilisation, where a competitor's behaviour and transactions are more predictable. The implicit gravitation towards market stabilisation results in the market's incumbent producers defining themselves as competitors and in doing so they intertwine inextricably their mental models into a shared industry identity with common beliefs. The intertwining of the mental models for a commodity market's incumbent producers can result in a cognitive oligopoly (Porac *et al*., 1989, pp. 398-414). Cognitive oligopolies represent a convergence and stabilisation in the mental models of incumbent producers in a mature market from the re-enactment of mutually favourable exploitative outcomes (Hodgkinson, 1997, pp. 641-646). The candidate argues that an executive team of a successful incumbent enterprise with a shared mental model that is nested within a broader shared mental model of a successful industry can develop a sense of confidence and control over the enterprise's destiny. Levinthal and March explain that a sense of confidence and control that is rooted in the past success and stability of an exploitative enterprise can result in its executive team setting explicit direction in employee selection processes. The explicit direction set results typically in the promotion of success and demotion of failure that is consistent with the expectation of performance outcomes (Levinthal and March, 1993, p. 109).

The proactivity dilemma contends that an exploitative enterprise will populate itself with employees that have a propensity for proactivity in exploitation.

**Exploitative executive mental models and exploration.**

The locus for managing the paradoxes of competing strategic imperatives and the engendering of appropriate cognitive frameworks resides typically in executive management teams (Smith and

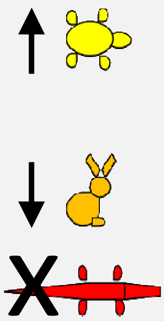
Tushman, 2005, p. 533). Strategic paradoxes incite a competition for the primacy of an enterprise's imperatives in the presence of entrenched organisational beliefs (March, 1991, pp. 73-74). The competing objectives from paradoxical strategic imperatives centre largely on the management of exploitative enterprise development and future growth strategies (Raisch and Birkinshaw, 2008, p. 399). Furthermore, the strategic objectives that an executive management team set may necessitate the reconfiguration of the enterprise's structure, processes and culture (Benner and Tushman, 2003, p. 247). The candidate's arguments have implied that strategic paradoxes will emerge during the course of normal technological development. The most salient of the candidate's implied paradoxes include those about proactivity, efficiency and learning. The proactivity paradox implies that an enterprise benefits in the short-term from a coherent proactivity focus but will suffer from it in the long-term. The efficiency paradox implies that an enterprise can not become efficient unless it is inefficient yet in becoming efficient it becomes vulnerable to inefficient enterprises. The learning paradox implies that an enterprise must learn about its product, processes and market in order to become efficient, which has the effect of inhibiting learning for a future that will entail inefficient products, processes and markets. Here, the candidate contends that a successful incumbent that has an executive management team with a shared exploitative mental model and is populated with employees that have a propensity for proactivity in exploitation is positioned poorly to recognise and act upon exploratory imperatives. Executive management teams that have a shared risk-averse exploitative mental model may become a fundamental source of an enterprise-wide inertia that inhibits exploration (Siggelkow and Rivkin, 2006, p. 793). Porter (1991, p. 115) described this inertia as "stickiness" in an enterprise that has stopped progressing. According to Barker (1993, p. 425), here the executive team are: "both under the eye of the norm and *in* the eye of the norm, but from where they are, all seems natural and as it should be". According to the candidate's metaphor, this entails a tortoise thinking like a hare or crocodile in an insidious boardroom. Porter (1991, p. 115) explained the importance of the fit and choice in leadership for the achievement of an enterprise's strategic imperatives. Here, the candidate contends that the strategic paradoxes that emerge from normal technological development may require a change in executive leadership in order to recognise and act upon strategic imperatives that may conflict the dominant focus in proactivity.

The candidate submits that the productivity, innovator's and proactivity dilemmas may be resolved through a meta-model of ambidexterity, which supersedes the biases of an enterprise's dominant focus in proactivity.

**Relationship between the productivity, innovator's and proactivity dilemmas.**

The relationship between the productivity, innovator's and proactivity dilemmas can be illustrated by the trends that emerge as an enterprise migrates from a non-efficient to an efficient state, which are shown in Table 39. Here, a poem from Zen Buddhism is presented, which the candidate believes captures the nature of the three dilemmas: "The wild geese do not intend to cast their reflection; the water has no mind to receive their image" (Watts, 1957, p. 200).

*Table 39: Relationship between the productivity, innovator's and proactivity dilemmas. Source: Candidate's design.*

| | **Enterprise characteristics.** | **Trend** (non-efficient to efficient). |
|---|---|---|
| **PRODUCTIVITY DILEMMA** Abernathy (1978). | Rigidness, routinisation and efficiency. | ↑ |
| | Innovation and learning capability beyond steady-state. | ↓ |
| **INNOVATOR'S DILEMMA** Christensen (1997). | Steady-state exploitation through customer-pull continuous incremental innovation. | ↑ |
| | Exploration for future. | ↓ |
| | Disruption vulnerability from external transformational and radical technology-push innovation. | ↑ |
| **PROACTIVITY DILEMMA** | Exploitation. |  |
| | Exploration. | |

### 7.5 AMBIDEXTERITY.

The candidate presents the state-of-the-art in ambidexterity theory in this section and develops their ambidexterity position that was outlined in Chapter 2 of this dissertation. There, the candidate argued that the duality concept of ambidexterity represents a static approach to innovation. The duality concept of ambidexterity argues that enterprises must excel in exploration and exploitation simultaneously.

#### 7.5.1 State-of-the-art in ambidexterity theory.

The ability to manage exploration with exploitation through ambidexterity is challenging contemporary researchers (Bessant *et al*., 2005, p. 1374; Gupta *et al*., 2006, p. 693; O'Reilly III and Tushman, 2008, p.185; Adler *et al*., 2009; Magnusson *et al*., 2009, p. 2). Whilst significant advances have been made in the understanding of the process behind this tension there has been no practical solution submitted that resolves the productivity and innovator's dilemmas (Adler *et al*., 2009, pp. 110-111). Key research areas at the macro-level include the resolution of the theory between the competing duality and punctuated equilibrium approaches to ambidexterity (Gupta *et al*., 2006). Accordingly, the issue of how ambidexterity modelling is impacted by the interdisciplinary theory of implied strategic imperatives and their appropriate fit in leadership remains unfulfilled (Raisch and Birkinshaw, 2008, p. 399). Moreover, how ambidexterity theory impacts the formation of enterprise alliances and their streams of value-adding activity (Lavie and Rosenkopf, 2006). Ambidexterity theory at the micro-level suffers from a deficiency in how it is applied and integrated throughout an enterprise's lower echelons and alliance partners (Gupta *et al*., 2006, pp. 703-704). Furthermore, significant research is required to prescribe accurately the appropriate tools and techniques that should be employed practically (Bessant *et al*., 2005, p. 1374). The candidate concludes that the state-of-the-art in ambidexterity theory can be summarised by the development of general guidelines that are devoid of prescriptive methods and a relationship to an overarching meta-model of ambidexterity, which is driven by contextual conditions (*e.g.* Brown and Eisenhardt, 1997, p. 32; Choi, 1995, p. 622; He and Wong, 2004, p. 492; Gupta *et al*., 2006, p. 703; Adler *et al*., 2009, p. 100; Magnusson *et al*., 2009, p. 3).

### 7.5.2 Framework for the candidate's meta-model of ambidexterity.

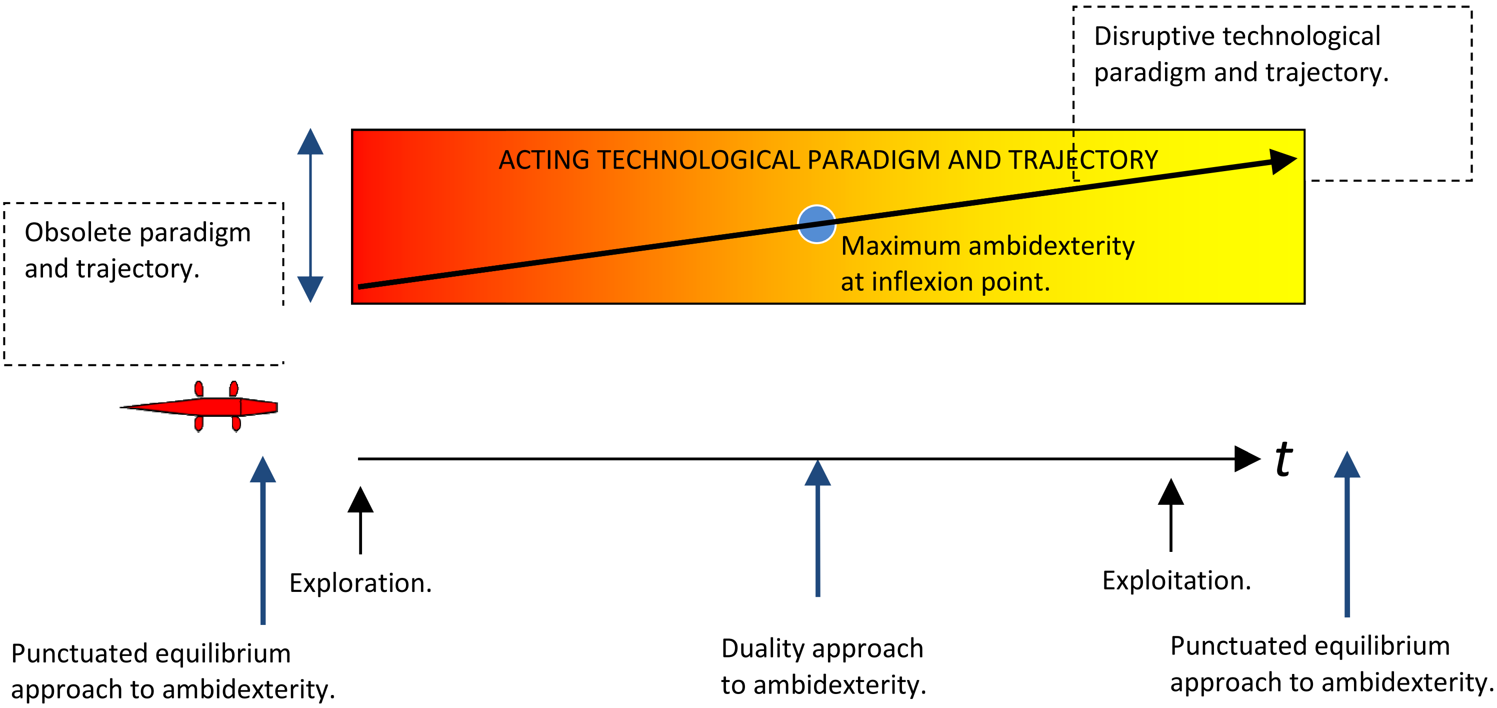
The re-introduction of uncontrolled variation in stable processes can reinvigorate knowledge creation. Innovation and adaptability may be precursed by sacrificing short term-efficiency in stable processes through deliberate perturbation, which embodies a duality approach to ambidexterity (Adler *et al*., 2009, p. 104). Setting deliberately the conflicting objectives of cost maximisation and cost minimisation through a duality approach to ambidexterity can improve an enterprise's financial performance (Balasubramanian and Bhardwaj, 2004, p. 489). The duality approach to ambidexterity can result in superior financial performance if it is applied under conducive contextual conditions (van Looy *et al*., 2005, p. 219; Uotila *et al*., 2009, p. 221). However, under certain contextual conditions a more effective approach to innovation is the pursuit of pure exploration or exploitation (Benner and Tushman, 2003, pp. 252-253; Drnevich and Kriauciunas, 2010). The application of a duality approach to ambidexterity has practical limits to its execution (He and Wong, 2004, p. 492) and is effective under contextual conditions where the complexity of innovation is not trivial or impossible (Miller *et al*., 2006, p. 720). Here, the candidate re-asserts that a duality approach to ambidexterity has limited application and can be regarded as a static approach *per se*.

**Migration in ambidexterity approach.**

The candidate argued in Chapter 2 of this dissertation that a duality approach to ambidexterity can be resolved within a punctuated equilibrium approach. Here, the candidate submits that the approach to ambidexterity must align with the contextual conditions that it operates under, which are implied by the theory of normal technological development. The framework for the candidate's overarching meta-model of ambidexterity is shown in Figure 17.

The candidate asserts that the maximum benefit from a duality approach to ambidexterity exists at the inflexion point of a technological paradigm traversing along its technological trajectory.

***Figure 17: Framework for the Candidate's ambidexterity model. Source: Candidate's design.***



**7.6 SUMMARY.**

This chapter developed the theory for the transposition of the findings from the testing of hypotheses in Chapter 6 of this dissertation to processes other than manufacturing (quality management, supply chain management, product development *etc*.). The state-of-the-art in the theory for the productivity dilemma, innovator's dilemma and ambidexterity was established. The theory for the candidate's concept of a proactivity dilemma was developed.

The candidate submits that their formation of the theory in this chapter achieved substantially the outcome that was planned in the strategic argument mapped in Table 3 of this dissertation. There are three key parts to the outcome, which can be summarised as follows. Firstly, the findings from the testing of hypotheses in Chapter 6 of this dissertation can be transposed from manufacturing to processes other than manufacturing through an **explore-explore continuum**. Secondly, the theory for the proactivity dilemma works in concert with the productivity and innovator's dilemmas. Thirdly, the framework for the candidate's ambidexterity model was defined.

# CHAPTER 8
# AMBIDEXTERITY MODEL

## 8.1 INTRODUCTION.

The findings from the testing of hypotheses in Chapter 6 of this dissertation are transposed to processes other than manufacturing, according to the strategy in Table 3 of this dissertation. Nine core processes for a typical manufacturing enterprise are addressed by the candidate, which are categorised under operations management, product development and strategic planning. The findings from Chapter 6 are transposed to each process individually, in order to establish the unique explore-exploit continuum for each process. The compatibility of the individual transpositions is tested as a complete unit against a Systems Analysis Tool. The results are evaluated and are applied towards the development of the candidate's ambidexterity model.

## 8.2 ORGANISATIONAL DISAGGREGATION BY CORE PROCESS.

The candidate has argued that the hypotheses submitted in Chapter 6 of this dissertation can be transposed to other processes through an explore-exploit continuum. Here, the hypotheses are transposed in four steps. Firstly, the strategic imperatives of a manufacturing enterprise are defined within the context of the candidate's analytical framework in Chapter 4 of this dissertation. Secondly, the core processes of a typical manufacturing enterprise are disaggregated from the enterprise and examined individually in order to determine how they can best support exploration and exploitation. The examination of core processes is achieved by establishing the theory for their function, the core methods and tools for their execution and how the processes can be managed strategically through an explore-exploit continuum. Thirdly, the processes are reaggregated and tested for compatibility against a Systems Analysis Tool. Fourthly, the evaluation of the compatibility results is applied towards the development of the candidate's ambidexterity model.

### 8.2.1 Crossing the internal chasm.

Bernstein and Singh (2008, p. 385) argue that the adoption of an innovation within an enterprise must cross an internal chasm, which is akin to the crossing of an adoption chasm for a new technological paradigm in the establishment of a market. Here, the candidate argues that the adoption of an innovation within an enterprise is influenced by the exploratory forces of **expansion** and the exploitative forces of **integration**[103], which reflect the political alliances and functional

[103] Evidence of the explore-exploit dichotomy in Australia exists in key industry literature. *E.g.* Automotive supplier excellence Australia (ASEA) identified the key success characteristics for Australian suppliers in 2009 and beyond. ASEA's vision was a supplier that "Enhances research & development activities to deliver value outside traditional boundaries, and understands the contribution that R&D makes to the broader business (exploration)" yet "Leverages technology and innovation to reduce cost, risk and improve quality (exploitation)" (ASEA, 2008, p. 10). Similarly, the Australian federal government's "Bracks" review into the Australian automotive industry found that restructuring to lean manufacturing was required (exploitation) (Commonwealth of Australia, 2008, p. 65) whilst simultaneously endorsing increased funding in R&D to encourage growth and technological overspill (exploration) (Commonwealth of Australia, 2008, p. 31).

agendas of those concerned in the adoption decision making process. Table 40 provides provocative examples of exploratory and exploitative narrative that may emerge.

*Table 40: Examples of exploratory and exploitative narrative.*
*Source: Candidate's design.*

| | EXPLORATORY NARRATIVE (EXPANSION) | EXPLOITATIVE NARRATIVE (INTEGRATION) |
|---|---|---|
| **Manufacturing.** | "This new technology, though expensive and risky, will allow us to do and make new things." | "Make the products fit our existing tooling, process *etc*. We could be more efficient and have already invested a lot." |
| **Quality.** | "We can contain defects through 100% inspection and rework until we get established." | "It should be fully tested and proven. Defects are unacceptable and a sign of failure." |
| **Marketing.** | "This has great potential; get manufacturing to figure out how to make it." | "We can lower costs and grow the market if we rationalised our base product and offered custom options." |
| **Finance.** | "For some short-term pain, we could get long-term gain. This opportunity is too great – we can not afford to pass it up." | "We are already close to this year's budget, and even if this idea works, we will not see returns for at least 3 years. We are better off investing in more automation." |
| **Design.** | "Imagine if one day every car had fuel injection." | "Imagine if we could make the cheapest, most reliable and efficient carburettors in the world." |
| **Purchasing.** | "Where can we find someone who can make fuel injectors?" | "In return for sole sourcing, our supplier can make carburettors cheaper, more reliable and efficient than our competitors". |
| **Human resources.** | "We need people who will shake up the place." | "We need people who will fit in." |
| **Boardroom.** | "How can we get a pay-off so shareholders jump onboard?" | "Our shareholders expect another dividend this year". |
| **Shareholders.** | "This will pay off in the long-run." | "We expect a dividend this year." |
| **Customer.** | "That sounds like a good idea." | "This is what I want." |
| **Competitors.** | "This technology will wipe out our competitors." | "This improvement will put us ahead of our competitors." |

### 8.2.2 Strategic imperatives.

A question that requires resolution in order to develop an ambidexterity model is what are the strategic imperatives that an enterprise should pursue according to the hypotheses in Chapter 6 of this dissertation? A framework of strategic imperatives has two functions. Firstly, it guides the development of the explore-exploit continuums. Secondly, it provides the basis for a model of ambidexterity that supersedes the biases of an enterprise's dominant focus in proactivity.

**Migrating strategic focus and competitive advantages.**

The hypotheses in Chapter 6 of this dissertation imply that there is a systemic migration in strategic focus and competitive advantages during the normal development of a technological paradigm. Here, the candidate applies Francis and Bessant's (2005, p. 172) "4P's" Model of Innovation Targeting in order to categorise where strategic focus is directed and competitive advantages are found. Table 41 summarises the migration in strategic focus and competitive advantages that occur during the normal development of a technological paradigm according to the candidate's hypotheses.

*Table 41: Framework of strategic imperatives.*
*Source: Candidate's design.*

| | EXPLORATION | MIGRATION <---> | EXPLOITATION |
|---|---|---|---|
| **Strategic focus** | | | |
| **Paradigm** | Create paradigm. | Embed paradigm. | Optimise paradigm. |
| **Position** | First to market. | Early to market. | Late to market. |
| **Product** | Generate intellectual capital. | Define dominant design. | Optimise dominant design. |
| **Process** | Organic process. | Economies of scale. | Efficiency and mass customisation. |
| **Competitive advantage** | | | |
| **Paradigm** | Novelty, brand and pioneer image. | Establishment of industry locus and benchmark. | Redefinition of industry locus and benchmark. |
| **Position** | Intellectual capital stronghold. | Rapid growth and market leadership. | Market stability and redefined leadership. |
| **Product** | Fluency of product and consumer concepts. | Standardisation. Leadership image. | Cost, quality, performance reputation, new loyalties. |
| **Process** | Organic invention and novelty creation. | Production organisation. Sunk cost. | Production reorganisation. Supply chain. |

**8.3 OPERATIONS MANAGEMENT.**

Operations management comprises the core processes of manufacturing, quality and supply chain management. Here, the candidate examines individually the potential of each process to best support exploration and exploitation.

**8.3.1 Manufacturing.**

The candidate believes that sufficient evidence has been presented in previous chapters of this dissertation in order to submit immediately the relationship between strategic focus and appropriate manufacturing paradigm. The strategic focus is characterised by a migration from **inefficiency** to **efficiency** and is defined in Table 42.

*Table 42: Relationship between strategic focus and appropriate manufacturing paradigm. Source: Candidate's design.*

| FOCUS | INEFFICIENCY (exploration) | MIGRATION <---> | EFFICIENCY (exploitation) |
|---|---|---|---|
| | Craftsmanship | Mass production. | Lean manufacturing. |

**8.3.2 Quality management.**

The candidate contends that the process of quality management (QM) within a technological paradigm can be encapsulated by the migration from the reactive detection of defective outputs from an enterprise's process to the proactive prevention of defects through the control of that process's inputs.

8.3.2 (a) QUALITY MANAGEMENT FUNCTION.

The concept that unprevented defects result in an ongoing accumulation of waste magnified the scope of QM as a core process in manufacturing enterprises. The cumulative waste of defects provoked a systemic approach to quality control (QC) that integrated the final customer. According to Feigenbaum (1956, p. 94): "control must start with the design of the product and end only when the product is in the hands of a customer who remains satisfied".

**Customer satisfaction and quality costs as a loss to society.**

The systemic approach to QM introduced the principles of an internal customer and waste from defective quality as a loss to society. The internal customer principle asserts that each participant in a process has the triple role of being a customer who receives inputs, a processor who transforms inputs into outputs and a supplier who supplies outputs to the next customer (Juran, 1979 cited in Bicheno, 1994, pp. 8-10). The principle of waste from quality costs as a loss to society is reflected in the context of an enterprise by Deming (1993, chapter 2), who argued that waste affects motivation and morale. Deming argued that if employees are engaged in the elimination of quality borne waste then their motivation and morale are stimulated intrinsically. Moreover, the provision of defect-free quality results in customer satisfaction for the internal customers and the end customer. The principle of waste from quality costs as a loss is reflected in a broader perspective by Taguchi, who argued that defects are a loss to society in general (Taguchi 1985, cited in Bicheno, 1994, p. 16).

The pursuit of preventable waste through quality management translated directly into accounting practice, which delineated quality costs by the categories of defect prevention, appraisal and failure (Standards Australia, 1982).

**Variation.**

Perfect quality in QM is framed as a nominal state, which may be interrupted by disruptions in the flow of a prescribed process. Disruptions in a prescribed process are regarded as variation, which must be eliminated in order to prevent waste (Deming, 1993, Chapter 2).

**Continuous incremental improvement.**

The concepts of internal customers and process variation can be regarded to form the framework for the QM function, which strives for the enhancement of customer satisfaction through continuous improvement (CI) in the elimination of variation throughout a stream of value-adding activity. The most common tactic is the Plan–Do–Check–Act (PDCA) cycle, which forms the basis for a raft of core processes and tools[104] (Bicheno, 1994, pp. 6-7). PDCA embodies CI and the concept of accumulation by the manner that the outputs from a preceding phase become the inputs for the proceeding phase in a never ending cycle. Whilst PFCD provides a tactic, the underlying philosophy of CI is incremental improvement that accords with a *kaizen* approach to innovation (Peng *et al*., 2008).

**ISO 9000.**

The successful application of QM across Japan's manufacturing industries led to external emulation. ISO 9000 was conceived as a global standard the defined the norms for quality management systems (QMS) and how they are implemented. There were more than 400,000 ISO 9000 certificates of compliance issued across 158 countries by 1999 (Guler *et al*., 2002, p. 209). Almost 900,000 certificates were issued by 2006 (Martinez-Costa *et al*., 2009, p. 495), which comprised more that 130,000 Chinese enterprises (Zeng *et al*., 2008, p. 51). ISO 9000 was released in Australia as AS 3900 in 1987 then as the joint Australia–New Zealand standard AS/NZS ISO 9000 in 1994 (Standards Australia, 1994a, p. i). The significance of ISO 9000 certification was that it sent a clear signal of a QM intent that made supply chain partnering easier (Arend and Wisner, 2005, p. 413). Furthermore, certification was perceived increasingly as a mandatory "order qualifier" (Sroufe and Kurkovic, 2008, p. 511).

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[104] The PDCA approach is fundamental to several organisational processes such as risk management, project management and product development, which if broken into principal phases mirror essentially PDCA. Accordingly, so do many quality tools such as 6 sigma, FMEA, QFD *etc.* and Juran's concept of project by project improvement (Bicheno, 1994, pp. 8-10).

**Quality professionals.**

The evolution of the quality professional's role is aligned with the progression of the dominant manufacturing paradigms, which is characterised by the "filing and fitting" of master craftsmen in 1886 to Ohno's path of autonomation (Jaikumar, 2005, p. 1). Quality in the CR era was the responsibility of master craftsmen who served as fabricators and self-inspectors. The machine driven dimensional control of the MP era resulted in the creation of the dedicated quality inspector's role, which was responsible for policing consistent part interchangeability. The reactive policing role of quality inspectors was challenged at the automobile paradigm's inflexion point by TQM, which resulted in a plethora of proactive QM specific analytical skills and statistical tools (Evans and Lindsay, 1989, pp. 279-284). The emerged role of a quality professional resulted in renewed debate about QM responsibility. Whilst QM can be regarded as the responsibility of all employees in an enterprise, the dilution of responsibility can result in a lack of clear ownership. Conversely, quality professionals can incite a general surrendering of ownership by non-quality professionals (Australian Quality Council, 1994a, p. 3-19). The candidate expects to show in proceeding sections that Ohno resolved pragmatically this debate through autonomation.

**QM as a business model.**

Several influential figures have argued that QM is more than a core organisational process and can be regarded as complete business model (*e.g*. Garvin, 1984; Deming, 1986; Feigenbaum and Feigenbaum, 1999). The core argument is that customer satisfaction is fundamental to the retention of existing customers and the securing of new customers. Here, the candidate observes similarity with the assertion of LM as a complete business model.

**8.3.2 (b) QUALITY MANAGEMENT AS A STRATEGY.**

The benefits from QM are realised when an enterprise has "profound knowledge" in its systems, products, processes, customers *etc*. (Deming, 1993, Chapter 4). A pre-requisite of effective QM can be regarded to be standardisation. The leveraging of past experience and the passing on of learning through standardisation reduces the time taken to accomplish tasks whilst simultaneously enhancing the reliability of outcomes and reducing variability in quality (March, 1991, p. 83). Standardisation represents the codification of the generic knowledge available in an industry and an enterprise's specific intellectual capital (Sroufe and Kurkovic, 2008, p. 513). High performance in QM is found in enterprises that are able to satisfy consumer needs and perceptions (Garvin, 1984, p. 42; Hines *et al*., 2002, p. 7).

The candidate asserts that QM as a strategy is most effective under the contextual conditions that are characterised by the exploitative customer-pull era of a technological trajectory.

**Competitive advantages from quality management.**

Sroufe and Curkovic (2008, p. 517) argue that the true competitive advantages derived from QM are not the implementation of a QMS *per se* but the way an enterprise executes the underlying principles of the QMS. The following section establishes how an enterprise can optimise the benefits from a QMS.

***Quality and integration.***

Sroufe and Kurkovic researched the implementation of ISO 9000:2000 within the automotive industry and found that the greatest beneficiaries from the QMS's implementation were enterprises that had achieved high levels of integration with their supply chain (SC) and customers. Proactive integration in value-adding streams rather than reactive compliance was regarded to be a defining factor in the selection of potential SC partners (Sroufe and Kurkovic, 2008, pp. 516-517). A similar study by Yeung concluded that proactivity in the pursuit of quality outcomes induces integration within SCs because of the competitive advantage in efficiency that could be achieved. The inducement for integration acted regardless of an enterprise's size or process type (Yeung, 2008, p. 500). Kaynak and Hartley investigated the relationship between the integration of a SC's partners and QM performance and concluded that supply chain integration (SCI) has a positive relationship with QM performance (Kaynak and Hartley, 2008, p. 483). Farrell *et al*. investigated the incentives for SCI and argued that the total systemic quality of a SC is not necessarily the sum of its components and that often a weak-link principle applied. The weak-link principle contends that customer perception is limited typically to the component(s) of minimum quality, which provides the SC incentive to improve its weaker elements through integration and homogenisation and the dissemination of its stronger elements through standardisation and capability development (Farrell *et al*., 1998, p. 162).

***Integration and customer orientation.***

Fortanier *et al*. (2007 p. 196) argue that the profitability of an integrated enterprise increases when its orientation responds to the dominant pressures of the industry it competes in. Braunscheidel and Suresh researched the relationship between a SC's responsiveness to competitive pressures in the context of stable and turbulent environments. SC's that are oriented towards the provision of customer satisfaction in a stable customer-pull context were found to be characterised by high levels of integration, which encompassed integration within a SC partner's internal processes, between SC partners and with the end customer (Braunscheidel and Suresh, 2009, p. 135). Braunscheidel and Suresh align with Christensen *et al*. who found that markets characterised by demanding customers are dominated by integrated enterprises (Christensen *et al*., 2002, p. 956).

***Integration, variation and financial performance.***

Several studies show that strong integration with customers and suppliers can provide improved financial performance through efficiency (Braunscheidel and Suresh, 2009, p. 134). Flynn *et al*.

corroborated the relationship between SCI and improved financial performance and added that integration is cumulative a process, which is characterised by a threshold that must be achieved in order to realise performance gains (Flynn *et al*., 2010, pp. 66-67). The candidate argues that the threshold Flynn *et al*. found can be explained through the development of relational capital and the reduction of process variation from the SCI process. According to Lawson *et al*., the relational capital that is developed through close relationships, mutual respect, shared information and learning, frequent personal interaction and communication during SCI has a positive effect on financial performance (Lawson *et al*., 2008, p. 456). Commitment and trust are vital ingredients to the creation of stable and productive SC's (Yang *et al*., 2008, p. 605). The ongoing investment in the development of relational capital increases the benefits derived from SCI (Chang *et al*., 2008, p. 313). High levels of relational capital in a productive SC manifest frequently in long-term contracts and exclusive relationships between SC partners (Kamath and Liker, 1994, pp. 158-164; Hines, 1996, pp. 3-4). SCI and the formation of relational capital can be regarded to be precursors for the elimination of process variation throughout the SC, which has the effect of improving financial performance through improved efficiency. Germain *et al*. researched the effect of process variability on the financial performance of SCs and found a clear relationship between process variability and financial performance. Financial performance increases as process variation decreases regardless of the demand environment (Germain *et al*., 2008, p. 557). Furthermore, Bozarth *et al*. investigated the impact of process complexity in SCs on efficiency and found that process complexity within any SC partner had a negative effect on the efficiency of the entire SC. The impact that the reduction of process complexity throughout a SC has on financial performance provides a powerful incentive for the rationalisation of processes, products customers and suppliers (Bozarth *et al*., 2009, p. 89).

Quality management provides powerful incentives for supply chain integration in enterprises that are orientated towards customer satisfaction because of the competitive advantages provided through quality improvement and cost reduction. The financial performance of supply chains is increased by the collective elimination of variation throughout the supply chain's processes and the reduction of the supply chain's process complexity, which is facilitated by cooperative and stable relationships with high relational capital.

**Quality as an exploratory inhibitor.**

The literature for QM has centred greatly on the justification of QM practices and their effective execution (Hines *et al*., 2004; Sroufe and Kurkovic, 2008; Lopez-Mielgo *et al*. 2009).

The candidate observes that a fresh theme is emerging in the literature for quality management, which contends that quality management may inhibit exploration.

***Quality management systems and creativity.***

Jayawarna and Holt researched the issue of how QMS's promoted or discouraged the exploration and application of R&D knowledge in technology based companies. QMS's were perceived largely as the institutionalisation of routines that attempted to impose strict conformity, which had the effect of dampening creativity in exploratory R&D. R&D managers tended to resist QMS's on the basis that the contestation of knowledge and entrenched practices was a tenet of creative exploration (Jayawarna and Holt, 2009, pp. 782-784). The contestation of knowledge as a precursor of creativity was highlighted by Balasubramanian and Bhardwaj who warned about "excessive quality provision". Excess quality provision was characterised by a focus on interdepartmental harmony and coordination in the pursuit of quality objectives, which precluded the creative benefits that may arise from interdepartmental conflict (Balasubramanian and Bhardwaj, 2004, p. 500). Gilson *et al*. investigated the interplay between standardisation and creativity in the context of team-based quality initiatives for the provision of enhanced customer satisfaction. Gilson *et al*. argued for a balance between creativity and standardisation. Their analysis found that customer satisfaction was best achieved through standardisation, which was at the expense of creativity. Conversely, creativity was antagonistic to the achievement of customer satisfaction that is consistent with a quality focus (Gilson *et al*., 2005, pp. 526-530). Tilcsik (2008, cited in Adler *et al.*, 2009, p. 101) investigated the effects of selecting randomly industrial engineers and training them in ISO 9000 QMS. A stable pattern emerged that lasted 3 years after the training, which was characterised by an improvement in individual efficiency at the expense of creativity. Tilcsik argued that creativity had decreased because of diminished intrinsic motivation and the stunted cognitive models that are associated with TQM training. The effect that Tilcsik observed may be explained partially from the perspective of knowledge transfer. The research of Molina *et al.* (2007, p. 694) found that QMS's incite the search for more efficient processes and management by data because of the QMS's focus on the codification and transfer of knowledge. Jayawarna and Holt (2009, pp. 781-784) contend that QMS's are biased to a technical conception of knowledge that accumulates upon a fixed knowledge base, which has the effect of stifling exploratory inquiry that is not founded on data. This accords with Molina *et al*., who found that a strong QMS focus enhances manufacturing efficiency because it is able to measure performance based on data rather than creative intuition (Molina *et al.*, 2007, p. 694). Indeed, a deliberate emphasis on the use and generation of data for manufacturing efficiency at the expense of data that may be used in product innovation is an effective tactic for the optimisation of manufacturing efficiency (Bendoly *et al*., 2009, p. 320). QMS creates organisational routines that are consistent with incremental exploitation (Peng *et al*., 2008, p. 735), which have the outcome of efficiency enhancement (Monden, 1994, pp. 3-4; Yeung, 2008, p. 500). Here, the candidate argues that QMS's are unconducive to creative inquiry that is not founded upon established processes, technical constructs and constraints.

***Quality management systems and disruptive innovation.***

Whilst QMS's are compatible with incremental innovation there is a growing debate about QMS's compatibility with radical and transformational innovation (Cole and Matsumiya, 2007). Benner and Tushman researched the issue of how ISO 9000 influenced the generation of patents and found that proactivity and competency in ISO 9000 application resulted in increased exploitative patents at the expense of exploratory patents. Exploitative patents built on existing competencies and tended to continuous incremental improvement whilst exploratory patents focussed on novelty and the creation of new competencies (Benner and Tushman, 2002). Prajogo and Hong researched the effects of QMS's on R&D performance in mature enterprises by excluding young start-up firms from their investigation. The results showed that enterprises with high QMS integration in R&D directed significant innovation towards the enhancement of a product's quality, specification conformance, performance, reliability and durability[105] (Prajogo and Hong, 2008). The candidate argues that successful QMS forms a dichotomy with disruptive innovation. Disruptive innovation is intrinsically immature, which makes it inherently incompatible with effective QMS application. Disruptive innovators are typified by small start-up firms that are uncharacteristic of incumbent enterprises (Australian Technology Network, 2009). Moreover, disruptive innovators are exploratory by nature and strive to generate protected intellectual capital that has the capacity to destroy the competencies of incumbent industries (Killen, 2005a).

**Quality management and supply chain integration as routinised exploitation.**

QM and SCI share a common foundation, where SCI is complemented and induced by QM (Yeung, 2008, p. 490) and compounded by product and market homogeneity (Hilletofth, 2009. p. 17). The relationship between QM, SCI and ongoing sustainability has become a contemporary research issue (Bayraktar *et al*., 2007, p. 855; Sila, 2007, p. 84; Foster Jr., 2008, p. 465, Kaynak and Hartley, 2008, p. 468).

The candidate argues in the following sections that quality management and supply chain integration signify **routinised exploitation**.

**Coercive forces.**

QM focussed SC's with high integration generate powerful coercive forces that promote exploitation, which arise from the demands of interdependent and synergistic co-makership. Here, the candidate argues that QM focussed SC's with high integration observe the process behind the productivity, innovator's and proactivity dilemmas. According to Das *et al*., SCI can result in a loss of creativity

[105] Prajogo and Hong (2008, p. 860) also found a positive relationship between QMS's and new product innovation which could be argued to contradict the candidate's assertion that QMS's incite primarily exploitative innovation. The candidate counter argues that the metrics selected by Prajogo and Hong in order to measure new product innovation do not encompass effectively disruptive innovation. The candidate argues that the metrics selected are representative fundamentally of variants, options and improvements of existing products, which accords with the QMS maturity of the enterprises investigated.

through “rigidities that develop in routines and mental models that discourage independent thinking and innovative behavior” (Das *et al*., 2006, p. 567). The candidate argues that the coercive forces of culture, powerful customers and tightly interrelated activity streams act within SC’s and reinforce mutually.

***Culture.***

Kull and Wacker researched the cultural traits and behaviour that facilitated effective QM. The cultural traits that best facilitated QM were uncertainty avoidance and non-assertiveness. Uncertainty avoidance was characterised by behaviour that removed the uncertainty and unpredictability of future events, which was founded in team-building, collective reward and a systemic perspective of problem solving with a reliance on social norms, rules and procedures. Persons predisposed to uncertainty avoidance perceived risk as danger, ambiguity as threat, nature as controllable, feedback as important and dissent as intolerable. Moreover, innovation was regarded to be the cause of uncertainty, which resulted in a tendency for risk-averting group decisions and a preference for the preservation of the status quo. Assertiveness was associated with confrontation, uncooperation and aggression in relationships. Persons predisposed to assertiveness were perceived by uncertainty avoiding individuals to be driven by internal needs that apportioned blame and reward non-collectively. Assertive individuals regarded the source of problems and innovation to reside in individuals rather than systems, which resulted in a negative perception of QM. Uncertainty avoiding individuals perceived assertive behaviour as being competitive and incompatible with cooperation and a customer focus (Kull and Wacker, 2010). Antagonistic individuals and partner organisations within a SC are non-conducive to the cooperation required to achieve the collective benefit from QM (Feigenbaum and Feigenbaum, 1999, p. 29). QM focussed SC’s with high integration model their relational norms and systems of distributive justice for the allocation of risks and rewards according to behaviour that is consistent with the sanctioned culture (Narasimhan *et al*., 2008, p. 28). The sanctioned culture in turn shapes the perception of what constitutes risks and opportunities and the SC’s decision making processes (Dowty and Wallace, 2010, p. 64). The coherent recognition of risks and opportunities becomes embedded in organisational learning as the SC stabilises (Sorenson, 2003, p. 461-462). QM, SCI and the development of homogeneous capabilities throughout the SC act effectively as behaviour management tools (Zsidisin and Ellram, 2003).

***Powerful customers.***

Guler *et al*. investigated the global diffusion of ISO 9000 and found that a decisive factor in QMS adoption and certification within SCs was pressure from powerful downstream customers in the SC, which imposed a coercive and normative imitation process. Customer pressure was most prevalent in industries that induced competitive mimicry, which are characterised by a stable market that operates under powerful selection mechanisms (Guler *et al*., 2002. p. 226). Zhang *et al*. investigated the effects of relational stress in automotive SC's and found that downstream customers in a SC had greater success with their intervention in the development of upstream suppliers when high relational stress was present from their coercion (Zhang *et al*., 2009, p. 492). However, high relational stress and coercion from downstream customers can dampen the creativity of upstream suppliers. Jayawarna and Holt found that QMS's can have a "deadening effect" on exploration if they were imposed rather than developed according to an enterprise's unique contextual conditions (Jayawarna and Holt, 2009, p. 784). Moreover, according to Vijayasarathy, dominant downstream customers in a SC may dampen SC oriented innovation initiatives by their suppliers because of a perception of asymmetrical dependency and one-way communication (Vijayasarathy, 2010).

***Tightly interrelated activity streams.***

QMSs and SCI are effective because they provide a process focus that is integrated, visible, data-driven and underpinned by a collective approach to innovation and decision making. The QMS and SCI approach is regarded to constitute tightly interrelated activity streams, which are characterised by experience accumulation[106] (Zollo and Winter, 2002, p. 347, Lavie and Rosenkopf, 2006, p. 803), codification (Hendricks *et al*., 2007, p. 80; Molina *et al.*, 2007, p. 694; Sroufe and Kurkovic, 2008, p. 513), routinisation (Jayawarna and Holt, 2009, p. 775; Lopez-Mielgo *et al*., 2009, p. 538), rationalisation (Takeda, 2006, Chapter 9; Bendoly *et al*. 2009, pp. 312-315) and structural embeddedness with high investment in relational capital (Lawson *et al*., 2008, p. 456; Yang *et al*., 2008, p. 602). Moreover, the tightening of activity streams from QM can be compounded by the implementation of an environmental management system (EMS). Zutshi and Sohal researched this issue and found that manufacturing firms that implement an EMS in addition to a QMS amplify typically the focus on process-driven CI because of an EMS's concern with waste reduction (Zutshi and Sohal, 2004, p. 342).

The tightly interrelated activity streams of QM and SCI suffer the productivity, innovator's and proactivity dilemmas because of their tendency to impede anything but internally consistent change (Benner and Tushman, 2003, p. 238). High QM and SC integration results typically in a complex system (Bozarth *et al*., 2009), which has poor responsiveness to significant change (Rivkin, 2000; Das *et al*., 2006). An outcome from poor systemic responsiveness is inflexibility as an impediment to the adaptation to uncertainty (Das *et al*., 2006, p. 567-568) and a tendency to focus attention on increasingly marginal process improvements (Sorenson, 2003, p. 447).

[106] Examples of experience accumulation, codification and routinisation include: Standardised operating procedures (SOPs), QM tools that incorporate lessons learned, benchmarking and information databases *etc*. A growing trend is to incorporate QM and SCI software systems such as: Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Customer Relationship Management (CRM) (Hendricks *et al*., 2007, p. 80), Electronic Data Interchange (EDI) (Wu, 2003, p. 1370) and Supply Chain Optimisation (SCO) (Das *et al*., 2006, pp. 564-566).

**Quality management and sustainability.**

Porter asserts when an enterprise adopts QM as a business model the enterprise does not hold a strategic position (Porter, 1996). According to Porter (1996, p. 64): "Continuous improvement has been etched on managers' brains. But its tools unwittingly draw companies toward imitation and homogeneity. Gradually, managers have let operational effectiveness supplant strategy". Porter explains that QM is not a strategy *per se* but an element in the formation of a strategy[107] (Porter 1980 cited in Tidd *et al*., 2005, p. 120; Porter 1985 cited in Porter, 1996, p. 67). Competition through QM is centred on exploitative best-practice that strives continually to do things **better** than ones competitors, which Porter (1996) argues approaches a limit as an industry ages. Porter (1996) claims that whilst best-practice may be an important element in the formation of a strategy the essence of a sustainable strategy must be founded on doing things **differently** than ones competitors. The candidate located two papers that support partially Porter's (1996) assertions. Benner and Veloso researched the effect of the adoption of QM systems and practices on the financial performance of suppliers in the U.S.A. automotive industry. The financial performance from QM adoption was greater for early adopters than late adopters. Financial performance from QM adoption diminished generally with time for all adopters to the point where late adopters gain little benefit. Furthermore, enterprises with either narrow or broad technical diversity had the least potential to benefit from QM adoption (Benner and Veloso, 2008). Here, the candidate believes that narrow technical diversity and diminishing financial performance from QM reflects the exploitation of an aging technological paradigm. Martinez-Costa *et al*. compared the financial performance and level of enterprise integration for the 1994 and 2000 versions of ISO 9000 across a spectrum of manufacturing enterprises. The 2000[108] version of ISO 9000 represented greater alignment with the QM model of an integrated and systemic approach to CI than the 1994 version of ISO 9000. Whilst the 2000 version of ISO 9000 resulted in greater depth in integration and enhanced proficiency in QM practices than the 1994 version of ISO 9000, it did not manifest in a noticeable financial performance benefit (Martinez-Costa *et al*., 2009). The candidate argues that Martinez-Costa *et al.'s* (2009) result corresponds broadly to (Benner and Veloso, 2008).

***Quality management, supply chain integration and disruption.***

The competitive position of a mature SC that is centred on an aging technological paradigm is eroded by remaining integrated highly and not engaging in exploratory partnerships outside of the SC (Swink and Zsidisin, 2006). Routinisation and high sunk costs in relational capital can leave successful SC's

[107] Porter (1996) made the generalisation that Japanese companies rarely have strategies. Porter argued that the pioneering of practices such as TQM and CI in the 1970s to 1980s resulted in their predominantly Japanese adopters enjoying significant advantages in operational effectiveness through cost and quality. The competitive advantages from a customer-first orientation resulted in a trend of mimicry, which was characterised by enterprises "becoming all things to all customers" (Porter, 1996, p. 63). Accordingly, after a 6 year internal study of Toyota's business practices Osono *et al*. concluded that Toyota has no clear business strategy (Osono *et al*., 2008, p. xii).

[108] An Australian equivalent is AS/NZS ISO 9001 (Quality management systems-requirements), which mandates an enterprise-wide customer focus with the determination of customer needs and customer satisfaction levels as enterprise performance indicators (Standards Australia, 2000).

vulnerable to disruptive innovation because QM capabilities and architectures are fundamentally different to those required for exploration (Prajogo and Sohal, 2006, pp. 47-48, Choo *et al*., 2007, p. 928; O'Reilly III and Tushman, 2008, p. 190; Peng *et al*., 2008, pp. 734-738; Anand *et al*., 2009, p. 459).

***Quality management, supply chain integration and ambidexterity.***

The candidate observed that an emerging theme in the literature for QM and SCI is how to address the issue of ambidexterity in QM and SCI. Choo *et al*. investigated the effects of competency enhancement through QM and argued that the concentration of organisational learning towards exploitation can result in vulnerability to external disruption. Choo *et al*. proposed that loose coupling is required between the hard systemic and architectural elements of QM and the softer management practices of QM in order to accommodate exploratory learning (Choo *et al*., 2007). Schroeder *et al*. researched the state-of-the-art in the enterprise-wide QM practice of 6 sigma and suggested that a new model may be emerging, which allows an enterprise to act more organically in order to accommodate the antagonistic demands of exploration and control (Schroeder *et al*., 2008). Anand *et al*. investigated the relationship between infrastructure and effectiveness in CI for practices such as TQM, 6 sigma and LM and found that innovation in revolutionary process design in enterprises with an infrastructure that facilitated CI proficiency lagged the efforts to improve incrementally existing processes. A question that remains open is how to develop infrastructure that accommodates both radical and incremental process design (Anand *et al*., 2009, p. 456). Foster Jr. researched the state-of-the-art of QM in SC's and concluded that more research was required into the modelling of QM in SCs according to contextual conditions (Foster Jr., 2008, pp. 465-466). Craighead *et al*. call for greater research into the effect of a SC's knowledge and learning capability on the performance of its final downstream customer within the contexts of radical and incremental innovation (Craighead *et al*., 2009, p. 418). Peng *et al*. call for more research into how a SC's capabilities in exploration and exploitation are affected by their contextual conditions (Peng *et al*., 2008, p. 744). Moreover, Short *et al*. researched the state-of-the-art of how opportunities are perceived by enterprises and concluded that the relationship between how a SC frames exploitation and exploration as opportunities and the SC's processes and architecture is an open research question (Short *et al*., 2010, p. 59). Swink and Zsidisin note that there has been little theoretical development on the issue of the long-term effects of SCI with high relational capital (Swink and Zsidisin, 2006, p. 4225).

The candidate concluded that whilst progress is being made in the elements of ambidexterity in quality management and supply chain integration the issue of an encompassing meta-model of ambidexterity requires resolution.

**Quality management, supply chain integration and Toyota.**

QM and SCI resonate strongly with Toyota. Liker and Hoseus authored a text on Toyota's culture and explained that Toyota has an "obsession for quality" (Liker and Hoseus, 2008, p. 56). QM practitioners argue that Toyota's culture is equal to or greater than its tools and processes (Caldwell, 2008, p. 41). QM has theoretical alignment with LM (Monden, 1994, pp. 3-4). Furthermore, QM has been demonstrated empirically to be aligned with LM (Shah and Ward, 2003, p. 146; Dal Pont *et al*., 2008, p. 156). Moreover, LM is synergistic and has deep roots with SCI (Hines *et al*., 2002, p. 7; Das *et al*., 2006; Lawson *et al*., 2008; Hilletofth, 2009). The application of LM, QM and SCI can be regarded to be a model of incremental CI (Anand *et al*., 2009).

The candidate submits that lean manufacturing is an exemplar of quality management and supply chain integration.

**8.3.2 (c) CORE ENABLING METHODS AND TOOLS.**

QM has an array of methods and tools that are bundled frequently together. The candidate concentrates in this section on the QM methods and tools that originated from and are common throughout the automotive industry.

**ISO/TS 16949.**

The U.S.A. automobile producers Chrysler Corporation, Ford Motor Company and General Motors Corporation (CFGM) were not satisfied with ISO 9000, which was argued to foster an indirect approach to the quality of the products that were designed and supplied for them. CFGM contended that ISO 9000 allowed their SCs to have reliable processes that provided consistent replications of an inferior design (Guler *et al*., 2002, p. 209; Sroufe and Kurkovic, 2008, p. 504). ISO 9000 argues that a focus on customer satisfaction through reliable processes concludes inevitably in a superior product. CFGM cited the PDCA theory that quality is cumulative and used this to define explicitly their inputs into the SC's design and manufacturing processes through advanced product quality planning (APQP). CFGM's self-agreed standard QS-9000 embodied APQP and contended that accurate inputs into a reliable process that have a direct link to the downstream customer will result in accurate outputs, which can be realised through a prescription of QM tools. CFGM gained control over their SCs by imposing contractually QS-9000, which mandated that upstream suppliers must achieve formal approval from their downstream customers that their explicit needs have been met directly before supply is allowed to commence (Chrysler Corporation *et al*., 1995a, 1998a). A supplier's formal approval was controlled by CGFM and resulted increasingly in more explicit demands from CGFM (*e.g.* DaimlerChrysler *et al*., 2002). The concept of QS-9000 was adopted and modified by other mainstream automobile producers and consolidated through ISO/TS 16949, which superseded QS-9000 as a universally agreed global automotive standard for suppliers (ISO, 2002).

**Tool classifications.**

ISO/TS 16949 is less prescriptive in the QM tools that must be used compared to QS-9000 and places emphasis on a value-adding approach to process design and control, which can be argued to align closer with LM (ISO, 2002, pp. ix-x). However, the QM tools that emerged under the umbrella of QS-9000 can be regarded to be the mainstay of the automotive industry with significant overspill to manufacturing in general. Whilst QM tools overlap typically, the candidate argues that they can be classified according their primary function: control, optimisation and problem solving.

**Control tools.**

Whilst Deming defined the principles of variation management, the various statistical methods of process control provide the tools. The fundamental principle of variation management is to first bring a process into control by eliminating variation from special causes and then reducing variation from common causes whilst maintaining control (Deming, 1993). An example of variation from a special cause is tool breakage whilst normal tool wear produces common variation.

***Statistical Process Control (SPC).***

SPC was pioneered in U.S.A. and was applied widely by the 1930s. Deming visited Japan for a lecture tour in 1950 and introduced SPC to Japanese manufacturers, which helped inspire the Japanese quality movement (Monden, 1994, p. 222). SPC maps variation, which allows special causes to be identified and the trends of common variation to be revealed. SPC allows the concept of process capability to be realised through the application of variation limits. A capable process has less variation than its allowable tolerance according to an agreed buffer. An issue with SPC is that it is generally expensive to implement and maintain.

***Production Part Approval Process (PPAP).***

PPAP is a process for the approval of supply from a supplier and the setting of a benchmark for future changes. The key document is the Part Submission Warrant (PSW), which forms a legal contract through the co-signatures of customer and supplier. PSW constitutes a legal agreement that the customer is willing to accept the approved quality level and the supplier has the capability to guarantee ongoing supply according the approved quality level. Changes to the agreed quality level require the PPAP process to be repeated. PPAP encompasses several QM tools that include design verification plan and report (DVP&R), process control plan (PCP), measurement systems analysis (MSA) and failure mode and effects analysis (FMEA) (Chrysler Corporation *et al*., 1995b).

***Process Control Plan (PCP).***

The PCP is the primary production document that defines the control measures to be used in order to maintain normal production flow and reaction plans in the event of an aberration to normal production flow. Typical controls include standard operating procedures, preventative maintenance, gauging, calibration, inspection methods and measurement frequency, material handling, component identification and traceability. Typical reaction plans include breakdown procedures, quarantine, problem resolution and contingency measures *etc*. (Chrysler Corporation *et al*., 1995a; Schefenacker, 2006).

***Audit.***

Audits demonstrate compliance in QMSs and identify improvement opportunities (*e.g.* Chrysler Corporation *et al*., 1998b).

***Design Verification Plan and Report (DVP&R).***

DVP&R outlines the product verification schedule that proves a product's functional fitness and its achievement of customer and regulatory requirements. DVP&R's include typically the applicable specifications and regulations, test methods and schedule, acceptance criteria, design calculations, computer simulations and test results (Schefenacker, 2006).

***Measurement Systems Analysis (MSA).***

MSA measures the variation in measuring systems by determining repeatability and reproduceability (R&R) in order to ensure that the variation in SPC is fundamentally from the process being measured and not the measuring system. Repeatability reflects the consistency in repeat measurements and reproduceability reflects the consistency between multiple set-ups (Chrysler Corporation *et al*., 1995c).

***Inspection.***

Inspection is the measurement of a process or product to collect variable or attribute data in order to assess compliance and affect SPC. An example of variable data is the temperature of an injection moulding die and an example of attribute data is the number of various moulding defects on a decorative moulded surface.

***Mistake proofing.***

Fail-safe or fool-proofing devices originated primarily in Japan where they are called *poka yoke*[109]. The purpose of *poka yoke* is to eliminate SPC on the basis of cost and reliability. The instigation of SPC is attributed to Shewart in 1924 and was driven largely by the issue of how to overcome the need for 100% inspection in MP. SPC overcomes the issue of 100% inspection by measuring regularly samples that are considered to be representative of the entire population (Hayes and Romig, 1977,

[109] Also known as *baka yoke* (Ohno, 1988, p. 122; Monden, 1994, p. 12; Mika, 2006, p. 162).

p. 7). *Poka-yoke* is associated with Shingo as a key contribution to autonomation[110] in LM (Bicheno, 1994, p. 15). Shingo argued that SPC was unwieldy, costly and the closing of inspection gaps through mathematical inference is unreliable[111] inherently. Moreover, that the original quality intent may be lost where SPC becomes the object of focus rather than the process or process being measured. *Poka yoke* is the application of simple in-process devices and product features that act as passive 100% inspectors, which prevent defects from occurring at their source. The logic is that once an error is known then it should be eliminated permanently by preventing its occurrence at its source, which has the outcome of eliminating the need for SPC (Shingo, 1990, p. 204). Examples of *poka yoke* include assembly nests that do not accept incorrect size parts or product design features that only allow assembly in the correct configuration. A potential issue with a reliance of *poka yoke* is that the method requires a deep understanding of an enterprise's processes, which can be symbolised by a history of *kaizen* activity that was prompted by forced line-stopping. Here, the candidate argues that *poka yoke* can be regarded as an aspirational[112] QM method in LM and the informative nature of SPC can help the transition to *poka yoke* through the development of profound knowledge and learning (Deming, 1993, Chapter 4). Moreover, the candidate argues that the principles of SPC and *poka yoke* can ultimately be combined by methods such as genetic algorithms in closed loop self-monitoring processes, which combine the elimination of defects at the source with ongoing learning.

**Optimisation tools.**

The candidate contends that several advanced QM tools have the outcome of facilitating *kaizen*.

***Quality Function Deployment (QFD).***

QFD allows customer requirements to be identified systematically, ranked for importance and deployed throughout an enterprise. QFD emanated from Japan in the late 1960s and early 1970s and proliferated throughout U.S.A. in the 1980s and then globally (Chan and Wu, 2002, p. 463). QFD was developed by Akao (1990) and epitomises the LM philosophy that the voice of the customer should drive product design and value stream formation and be deployed throughout the enterprise by cascading the customer's requirements throughout all echelons and functions[113] of the enterprise (Chan and Wu, 2003, p. 24). QFD can facilitate concurrent engineering, reduced development time

[110] *Poka yoke* is recognised in LM as *jidoka* (autonomous defect control).

[111] Toyota use rarely advanced statistical tools such as 6 sigma *etc.* because they are considered to be too complex (Liker, 2004, p. 252). Furthermore, the concept of acceptable quality limits is despised philosophically because any level of defect tolerance regardless of how low can be damaging. The logic is that (externally) a customer only buys one product upon which they form their opinion and a single dissatisfied customer can yield considerable negative influence on brand reputation. Moreover, that (internally) defects interrupt production flow (Monden, 1994, p. 223).

[112] Toyota reacted to serious quality issues in 2006 by the implementation of SPC at its new Takaoke plant. According to President Watanabe (Watanabe, 2007 cited in Stewart and Raman, 2007. p. 82): Toyota will "use high-precision instruments to measure several parameters. The testing devices will be located at various stages of the assembly process and will provide data in real time to factory managers and suppliers". Here, the candidate argues that Toyota's reliance on *poka yoke* in a period of relative rapid expansion for Toyota may have lacked the profound knowledge required, which is symbolised by a return to SPC in order to gain greater depth in process understanding.

[113] There is no limit to the scope of QFD application within an enterprise. The customer's requirements are cascaded typically to product design, then value stream design and then the design of process controls (Prasad, 2000, p. 117).

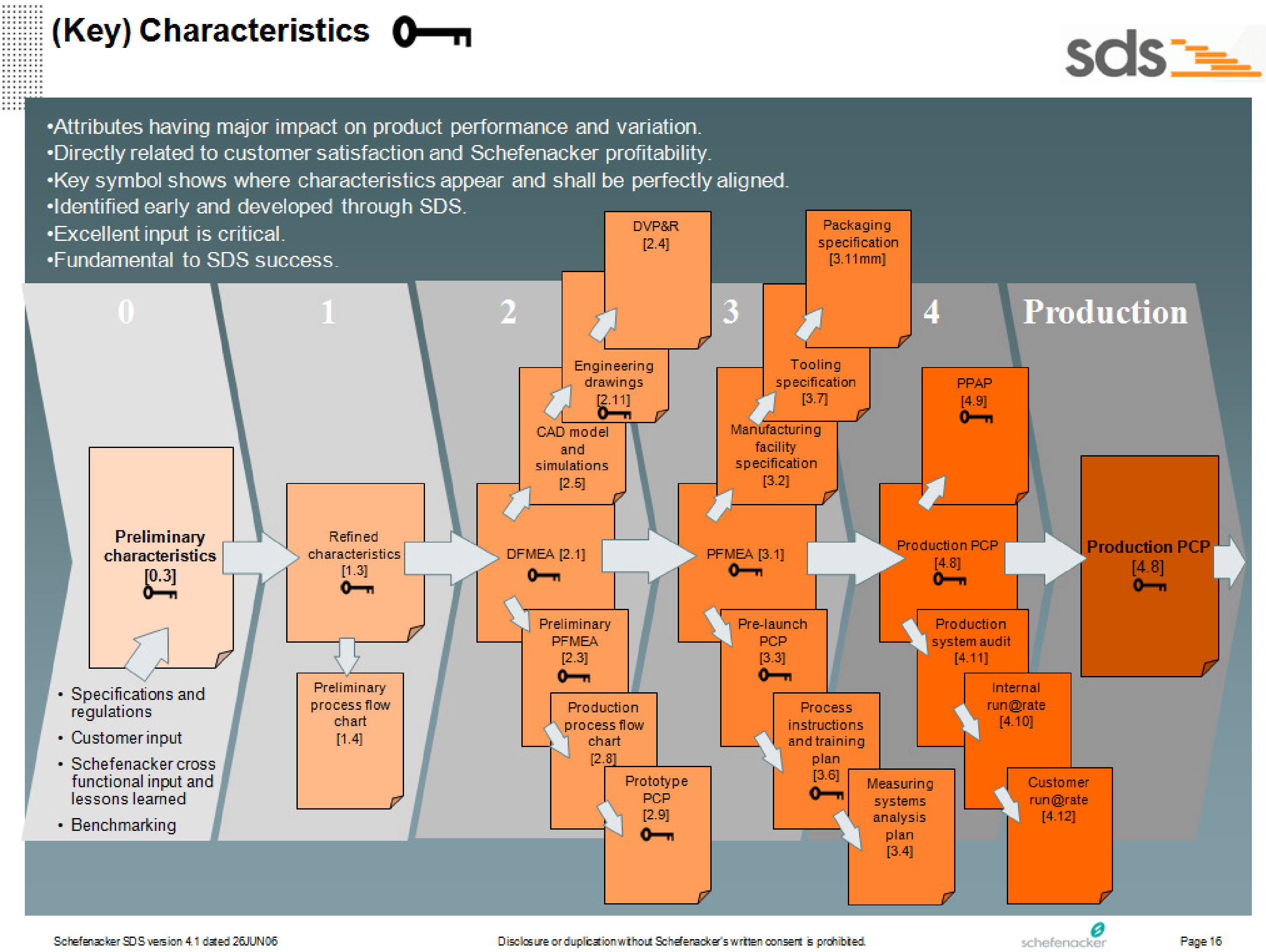
and efficient communication (Rose-Anderssen *et al*., 2005, p. 1094). The success of QFD depends upon accurate intelligence of the customer's requirements and a cross-functional team approach. QFD has the potential to unify[114] an enterprise as an executive management tool. However, QFD's demand for cooperation in the determination and processing of relevant data leaves QFD vulnerable to slow responsiveness (Prasad, 2000, pp. 107-108). Furthermore, the reactive approach of following the lead of customers can limit the forecasting of market opportunities and inhibit creativity (Cristiano *et al*., 2000 cited in Rose-Anderssen *et al*., 2005, p. 1094).

***Failure Mode (and) Effects Analysis (FMEA).***

FMEA is a quantitative risk management tool that codifies an enterprise's knowledge. FMEA identifies potential hazards and determines mathematically the priority for the treatment of risks, which is based on a probability that takes into account the severity of a potential hazard, its likely occurrence and the measures used for its detection. The severity of a potential hazard is rated between the extremes of customer annoyance to catastrophic fatality (*e.g.* Ford Motor Company, 1995). The underlying principle of FMEA is that hazards should be prevented and not detected, which is affected through the reduction of a hazard's occurrence. FMEA aligns with general risk management theory in that FMEA establishes the context of the risk assessment, identifies potential hazards and then analyses, evaluates and treats potential risks whilst communicating, consulting, monitoring and reviewing concurrently (*e.g.* Standards Australia, 1998, 1999). FMEA is applied typically during product and process design but can be applied at any level (Chrysler Corporation *et al*., 1995c). *E.g.* machinery design (Ford Motor Company, 1996). An important outcome from FMEA within the automotive industry context is that FMEA approval through PPAP constitutes an acceptance and benchmark of residual risk. Residual risk is the agreed level of risk at the approval of production supply, which codifies the supplier's risk treatment efforts and provides a platform for ongoing risk amelioration. Moreover, the primacy of FMEA in the APQP process overspills to other PPAP requirements that are illustrated in Figure 18.

[114] QFD as a management tool is similar to the Toyota method *hoshin kanri* (policy deployment) where key performance metrics are cascaded throughout the enterprise and are monitored and reported regularly (Liker, 2004, p. 262). QFD *per se* has been used in Toyota Japan since 1975 and now proliferates the entire Toyota enterprise (Chan and Wu, 2002, p. 465).

*Figure 18: The primacy of FMEA in the automobile industry's APQP and PPAP requirements. Source: Candidate's design, reproduced by permission* (Schefenacker, 2006).




### *Design of experiments (DOE).*

DOE is an advanced QM tool that integrates mathematically product design with manufacturing variation. DOE argues that a robust product design produces less manufacturing variation than a non-robust design and that the elimination of manufacturing variation through robust design reduces waste and the need for manufacturing quality control. Robust design is justified by the argument that the effort expended in robust product design is less than the effort required to dampen manufacturing variation from a non-robust design (Taguchi, 1998). DOE determines the optimal product design parameters that minimise variation through a complex mathematical procedure, which centres on a design of experiments (American Supplier Institute Inc. 1989). A potential issue with DOE is the need for high skills, relevant data and production resources.

*6 sigma.*

6 sigma integrates project management methodologies with the Deming PDCA cycle[115]. The differentiating factors of 6 sigma from other QM tools are deeper enterprise-wide integration, comprehensive packaging of multiple QM practices and financial reporting through progressive data-based reviews (Bicheno, 1994; Australian Quality council, 1994a; Ford Motor Company, 2005; Kwak and Anbari, 2006; Schroeder *et al*., 2008). Successful 6 sigma application requires extensive training, executive management commitment, cultural adjustment and SCI (Kwak and Anbari, 2006, p. 712), which is supported by a coherent human resource management system (Zu *et al*., 2008 p. 644). A potential issue with 6 sigma is that improvement projects may be selected on the basis of their compatibility with the 6 sigma approach because of 6 sigma's data intensity and integration with management practices (Zimmerman and Weiss, 2005, p. 62). The 6 sigma approach can be criticised for lacking strategic direction because of its capacity to be regarded as a business model (Kwak and Anbari, 2006, p. 713).

*Benchmarking.*

Benchmarking was developed by Xerox as a means of comparative analysis that determines the best-in-class attributes of a product or process in order to gain competitive advantages over rivals (Bicheno, 1994, pp. 49-51).

*Design For "X" (DF"X").*

DF"X" entails concentrating design effort towards the achievement of a specific outcome (X). A common outcome is DFMA (Design For Manufacturing and Assembly) but DF"X" can be applied to any outcome. *E.g.* design for recyclability, design for injection moulding.

**Problem solving tools.**

QM problem solving tools are characterised by the determination of the root causes of problems through evidence based rational decision making.

*5 Whys.*

The Toyota construct 5 whys asks "why?" five times in succession as a strategy to ensure that genuine root causes are revealed and reported.

[115] 6 sigma extends the Deming PDCA cycle to Define-Measure-Analyse-Improve-Control (DMAIC). Critics of 6 sigma argue that it does not offer anything fundamentally new. According to Schroeder *et al*. (2008, p. 537): "the philosophy and tools/techniques of Six Sigma are strikingly similar to prior quality management approaches". 6 sigma is attributed to Motorola and is different to "Sixth sigma". Sixth sigma entails analysis of the standard deviation of performance where the best normal events occur (nominally, but not necessarily the sixth sigma). Sixth sigma is used typically in service industries with the intent of understanding how the best (5%) operate, which can be implemented as a benchmark. 6 sigma strives to achieve a defect rate of less than 3.4 defects per million, which represents capability limits of 6 standard deviations for an in-control process.

***Ishikawa Diagram.***

Ishikawa diagrams are founded on the principle of cause and effect. Potential causes are listed and evaluated systematically, within the contexts of man, machine, method, material (4M's) (Bicheno, 1994, pp. 21-22).

***Pareto analysis.***

Pareto analysis is a prioritising tool that is based on the 80/20 rule, which states that 80% of the total problems can be attributed to 20% of the total causes. Pareto analysis complements Ishikawa diagrams (Bicheno, 1994, p. 21).

**8.3.2 (d) QUALITY MANAGEMENT CONTINUUM.**

According to Standards Australia (1994b, p. 7), quality improvement is defined as: "actions taken throughout the organization to increase the effectiveness and efficiency of activities and processes in order to provide added benefits to both the organization and its customers". The provision of benefit to the customer implies that "consideration has to be given to reduced costs, improved fitness for use, increased satisfaction and growth in confidence" (Standards Australia, 1994c, p. vii). The provision of benefit to the organisation implies that "consideration has to be given to increased profitability and market share" (Standards Australia, 1994c, p. vii).

An issue that requires resolution is how to balance the provision of benefit to the customer and the enterprise from the perspective of QM.

**Variable degree of quality provision.**

According to Standards Australia (1982, p. 16): "Whether the customer or the company itself dictates the degree of product conformance to specifications, it presents an economic problem providing a choice of alternate combinations of possible processes, degrees of quality control and investment in resources. In each instance, and optimal balance between product quality and the quality element in production cost is required". Furthermore, the degree of quality provision in product development should be moderated where "the sales or marketing organization will assess what the marketplace is willing to pay for a given value of quality in a product" (Standards Australia, 1982, p. 16).

The candidate contends that the analytical framework defined in Figure 7 and the hypotheses developed in Chapter 6 of this dissertation provide the contextual conditions that guide the moderation of quality provision.

**Strategically forsaken quality provision.**

The influential QM author Crosby advocated that the level of quality provision should not be based on acceptable quality levels but should be based on the standard of zero defects (Australian Quality

Council, 1994a, p. 4-5). Here, the candidate argues that quality provision can be forsaken strategically according to contextual conditions. Christensen *et al*. argue that the improvement of a technological paradigm from the producer's perspective almost always exceeds the capacity of the consumer to absorb the improvement. Furthermore, that a focus on the satisfaction of the most demanding consumers results typically with the over-satisfaction of less demanding consumers. Christensen *et al*. contend that the greatest competitive advantage through the provision of quality occurs in markets where consumers are under-served (Christensen *et al*., 2002, p. 961). The candidate observes that the contentions of Christensen *et al*. imply that the over-provision of quality is wasteful. Homburg *et al*. investigated the relationship between customer satisfaction as a function of quality and willingness to pay. The results revealed an inverse S-curve, which was characterised by diminishing marginal returns from raising the satisfaction levels of lowly satisfied customers up to an inflexion point where there was a shift to increasing marginal returns for investment from raising customer satisfaction to a high degree. Significantly, the centre portion of the S-curve that represented the mainstream market is relatively insensitive to the producer's quality improvement initiatives whilst the portion of the curve that is sensitive to the producer's improvement initiatives represented the most demanding consumers. Homburg *et al*. argue that the cost versus benefit from investing in extremely high levels of customer satisfaction may not be viable financially and that strategic differentiation in the provision of quality levels according to maker segment could be more profitable. A further important finding from Homburg *et al*.'s investigation was that customer satisfaction increases cumulatively with producer interaction and consumption experience from repeat purchases (Homburg *et al*., 2005). Here, the candidate argues that in addition to the manipulation of quality provision a producer can increase customer satisfaction through strategies that are designed to increase consumer loyalty through producer interaction and repeat purchases. Dube *et al*. explain that consumers exhibit typically loyalty to a previously purchased brand (Dube *et al*., 2008, p. 417). According to Lee *et al*., a consumer's loyalty to a previously purchased brand can influence their consumption efficiency where the consumer may choose a higher priced product over a cheaper product with same quality level based on the strength of a brand loyalty incited from previous purchases (Lee *et al*., 2008, p. 2967). Here, the candidate argues that the producer of the cheapest and best quality product can not assume that it will achieve market dominance because the producer's brand and the consumer's loyalty are moderating factors. Brand loyalty can be increased in addition to producer interaction and repeat purchases by the timing of the producer's entry into a market. Del Rio *et al*. explain the pioneering status that first-mover producers enjoy can create a positive brand image, which may command higher prices and remain relatively inelastic in response to the price changes of competitors (del Rio *et. al*., 2001, p. 413).

***Exploratory quality management.***

The candidate argues that customer satisfaction can be achieved without improving quality *per se* through early market timing, repeat purchases and the development of relational capital, which result in positive brand image. The candidate has established in previous chapters of this dissertation that QM in the technology-push context inhibits exploration and is not an object of focus[116] for the consumer. The candidate contends that exploratory QM should facilitate the generation of intellectual capital and rapid time to market through defect detection. Moreover, that the producer can influence directly the formation of the consumer's concept of quality and their expectations of the new technological paradigm, which can provide a platform for future exploitation through QM.

***Exploitative quality management.***

Whilst first-mover producers can secure a positive brand image through pioneering status, early follower and late entrant producers can exploit a positive consumer response from QM initiatives that are designed to enhance product quality (Shankar *et al*., 1999, p. 276). However, the consumer's response to QM initiatives tends generally to diminishing returns to the producer for the effort expended as the technological paradigm ages (Bowman and Gatignon, 1996, p. 240; Shankar *et al*., 1999, p. 269; Das *et al*., 2000, pp. 678-679). The candidate contends that exploitative QM can take advantage of the formed customer expectations and technological surety of a mature technological paradigm through the redefinition its industry's benchmark for cost and quality. Exploitative QM should facilitate efficiency through a migration from defect detection to defect prevention.

The candidate argues that the degree of quality provision for a technological paradigm should reflect the contextual conditions under which the paradigm operates and that the manipulation of the degree of quality provision can be managed strategically. The contextual conditions for QM as a technological paradigm ages are shown in Table 43.

***Table 43: Competitive advantage from Quality Management according to the maturation of a technological paradigm.***
***Source: Candidate's design.***

| Phase of maturation for a technological paradigm. | **EMERGENCE** | **CONSOLIDATION AND GROWTH** | **MATURITY AND DECLINE** |
|---|---|---|---|
| Benefit from competing through Quality Management. | Counterproductive initially then tending to minimal benefit. | Increasingly important with scope for rapid gains. | Fundamentally important but tending to diminishing returns. |

[116] *E.g.* Automobile Year (1982, p. 11) report paradoxically that some innovator adopters of the automobile during its origin gained satisfaction from mechanical breakdowns because they would draw a crowd and provide an arena for the innovator adopter to display their novel product. Moreover, it allowed the innovator adopters to exhibit their resourcefulness and prowess in technical skills. The candidate argues that this represents an example of where the customer-pull concept of quality management is disparate in a technology-push context.

**Migration from defect detection to prevention.**

The candidate submits that the explore-exploit continuum for Quality Management can be represented by a migration from defect **detection** to defect **prevention**, which allows an enterprise to secure first-mover advantages through a new technological paradigm and then exploit the new paradigm through quality management[117]. Table 44 summarises the candidate's submission.

*Table 44: Explore-exploit continuum for Quality Management. Source: Candidate's design.*

| FOCUS | DETECTION (exploration) | MIGRATION <---> | PREVENTION (exploitation) |
|---|---|---|---|
| **Boardroom strategy** | | | |
| **STRATEGY** | KEEP DEFECTS INVISIBLE TO CUSTOMER THROUGH INTERNAL CONTAINMENT. | REDUCE DEFECT OCCURANCE. LEARN. IMPROVE ROBUSTNESS. | PREVENT DEFECTS. OPTIMISE PRODUCT, PROCESS, SKILLS. VAVE. |
| **FINANCIAL MINDSET** | *"Cost of doing business"* | *"Cost-down opportunities"* | *"Profit optimisation"* |
| **PRIMARY COST CENTRE** | Detection costs. | Appraisal costs. | Prevention costs. |
| **Shopfloor tactics** | | | |
| **INSPECTION PURPOSE** | Remove defects through judgement and attribute gauging. | Reduce defects through informative feedback and variable gauging. | Eliminate defects by going to source. |
| **RESPONSIBILITY** | Dedicated inspectors. | Quality professionals with operator input. | Autonomous, cross-functional and empowered staff. |
| **CULTURAL INVESTMENT** | Defects tolerated but must not reach customer. Focus on product function and utility. Defect and efficiency improvement must not retard invention, IP capital generation or time to market. Flexibility in dramatic product specification and process changes. Ability to focus on "big picture". | Deepen customer loyalty and enhance positive brand status. Identify and prioritise improvement opportunities. Improve operating efficiency. Improve product cost, performance and reliability. Understand process inputs and component variation. | Focus on continuous improvement, multi-skilling, integration, consensus, using lessons learned and experience, corporate and supply chain learning and policy deployment. Customer-first orientation with proactive, engagement in waste exposure and elimination. |

117 The candidate contends that the Microsoft Corporation can be regarded to provide an example of the candidate's submission. Here, the candidate argues that Microsoft entrenched a dominant design for software systems as a *de facto* industry standard despite the dominant design being flawed. Microsoft was then able to exploit the flaws in the dominant design through QM.

| | | | |
|---|---|---|---|
| | *"Teach customers what they want".* | Focus on standardisation, specification development and control with customer orientation. Document and disseminate lessons learned. Develop profound knowledge. *"Consider both internal and external customers".* | Desire to enhance customer satisfaction. Utilise profound knowledge. *"Ask customers what they want".* |
| **CORE METHODS** | 100% EOL product inspection, containment, rework, scrap. Output control at product level. | SPC sampling, charting and analysis. Successive in-process component operator checks. Process start-up and run control PPM/capability targets. Process and product audit. Management review. Migration from output control at product level to input control at process level. | Customer and supply chain integration, feedback and service metrics. Codification. *Kaizen*. Waste elimination at source. First time through yield. Autonomation: *Jikoda, Andon, Poka Yoke*. |
| **ENABLING TOOLS** | Automated test/reject or manual check against quality standard. Go-nogo (attribute) gauging. Dedicated quarantine area with rework and scrap procedures. | Quality management systems and certification. Traceability and documentation. Variable gauging. Flow chart, PCP, FMEA, PPAP, MSR, R&R, DOE, DF"X". Lessons learned/warranty analysis: 5 whys, Pareto and Ishikawa. Benchmarking. Dedicated problem solving (quarantine) area with specialist metrology equipment. | Value stream mapping (synchronised flow). Closed loop monitoring (with genetic algorithms). PDCA, 6 sigma, QFD, 5S visual management to expose waste and abnormal conditions (no quarantine area). |

### 8.3.3 Supply chain.

The candidate contends that the process of SCI within a technological paradigm can be encapsulated by the migration from disintegrated processes within an enterprise to processes that are integrated with the enterprise's customers and SC.

#### 8.3.3 (a) SUPPLY CHAIN FUNCTION.

SCs are collaborative relationships that are formed between separate enterprises in order to achieve a mutually beneficial strategic purpose (McCarter and Northcraft, 2007, p. 502, Flynn *et al*., 2010, p. 59, Lockstrom *et al*., 2010, p.241, Nyaga *et al*., 2010, p. 101). SCs are formed by the integration of the internal processes of individual enterprises with their customers and suppliers through agreed participation. The coordination and synchronisation of processes through integration can reduce the dysfunctional aspects of exchange transactions (Narasimhan *et al*., 2009, p. 374). Process coordination can result in the optimised flow of work, materials, information, resources and cash (Hines, 1996, pp. 3-4). Furthermore, SCI can provide access to external intellectual capital, knowledge and capabilities (Craighead *et al*., 2009, p. 406). The theory for SCI has deep roots in Toyota (Hines, 1996, p. 3; Shah and Ward, 2003, p. 129; Papadopoulou and Ozbayrak, 2005, p. 790; Corbett and Klassen, 2006, p. 6; Schonberger, 2007, p. 413, Yu *et al*., 2009, p. 791). Toyota exploited synergistic relationships with its suppliers in order to add maximum value to downstream customers (McCarter and Northcraft, 2007, p. 502; Flynn *et al*., 2010, p. 59). SC's avail themselves to customer-pulled value streams with the aspiration of becoming a seamless conduit for the provision of value to the end user (Vijayasarathy, 2010). A seamless conduit can be affected through an uninterrupted flow of materials (Ellis *et al*., 2009, p. 34), predictable demand levels (Germain *et al*., 2008, p. 569) and reduced inventory (Lockstrom *et al*., 2010, p.241), which accords with JIT flow (Hilletofth, 2009, p. 16). Toyota fostered collaboration with its SC through a reduction of its overall supplier base and a concentration on the development of exclusive[118] relationships and contracts with selected suppliers (Kamath and Liker, 1994, pp. 158-164; Hines, 1996, p. 4). Furthermore, collaboration was promoted by Toyota's significant investment in the development of its suppliers' capabilities (Liker and Choi, pp. 107-112) and the sharing of financial rewards (Flynn *et al*., 2010, p. 59). Toyota's SCI created significant gains in manufacturing efficiency, which remains the primary function of a SC and constitutes a major theme in contemporary SCI research (*e.g*. Ireland and Webb, 2007, p. 494; Yeung, 2007, p. 490; Narasimhan *et al*., 2009, p. 374; Nyaga *et al*., 2010, p. 101; Lockstrom *et al*., 2010, p.241).

**8.3.3 (b) SUPPLY CHAINS AS A STRATEGY.**

The efficiency that SCI can achieve has driven the formation of massive SCs. The size of SCs *per se* is becoming increasingly influential as an integrating force with potential SC alliance partners (Vijayasarathy, 2010, p. 489). McCarter and Northcraft (2007, p. 498) highlight that SCs are beginning to displace independent enterprises as competitive entities. Moreover, the importance of SCs is growing for manufacturing enterprises that are globalising increasingly because of a trend to global sourcing and distribution (Cagliano *et al*., 2008, p. 93). Increasingly, the activities of a global enterprise's SC and the outcome on financial performance is becoming coupled tightly (Craighead *et al*., 2009, p. 405). The competitive advantages that efficient SC's provide have resulted in a new form of competition between SC's, which is characterised by SC's seeking to gain competitive advantages over rival SC's in what they can offer potential customers (Foster Jr., 2008, p. 461). The strategic implications from the selection of SC partners and SCI has spurred a raft of research themes in the literature for SC management, which include the identification and mitigation of risks that can interrupt production flow (Knemeyer, 2009; Narasimhan and Talluri, 2009; Neiger *et al*., 2009), the behavioural implications of trust, power and partner perceptions (Zhao *et al*., 2008; Narasimhan *et*

[118] The candidate argues that the logical conclusion from fostering supplier collaboration through exclusive relationships is single-sourcing. However, Toyota does not single-source, which has relational implications that are explained in Appendix A of this dissertation.

*al*., 2009; Ellis *et al*., 2010; Nyaga *et al*., 2010), decision making and problem solving (Cantor, 2009), knowledge management (Craighead *et al*., 2009; Fugate *et al*., 2009), differences in geographical cultures (Naor *et al*., 2010; Power *et al*., 2010), stock price performance (Hendricks *et al*., 2009) and marketplace differentiation (Hilletofth, 2009). Moreover, the candidate contends that new themes are emerging that are related to the productivity dilemma, which include SC flexibility (Chandra and Grabis, 2009) and the locus of innovation responsibility and intellectual capital ownership (*e.g.* Petersen *et al*., 2005; Koufteros *et al*., 2007; Song and Di Benedetto, 2008; Stock and Tatikonda, 2008; Lockstrom *et al*., 2010).

**8.3.3 (c) CORE ENABLING METHODS AND TOOLS.**

Successful SCI emphasises strategic and cultural alignment, which is characterised by non-adversarial relationships and an emphasis on behaviour that optimises the profitability of the collective SC ahead of individual enterprises (Braunscheidel and Suresh, 2009, p. 135). According to Sprague (2007, p. 235): "Optimizing the supply chain means convincing elements within that system to accept local suboptimums for the good of the whole". Moreover, successful SCI requires the elimination of opportunistic price strategies in favour of benevolent price strategies that promote cooperation (Narasimhan *et al*., 2009, pp. 378-379).

The candidate argues that SCI employs methods and tools that facilitate a shared destiny through integration and behavioural control.

**Trust and relational capital.**

Integrated SCs gravitate toward partners with complementary capabilities and strive to develop trust in order to share knowledge for mutual competency enhancement (Feller *et al*., 2006, pp. 178-188). Trust can be considered to have a foundational role in SCI as a pre-requisite to alliance building and the achievement of financial performance through integration (Narasimhan *et al*., 2008, pp. 28-29). Whilst a degree of trust may be created through exclusive partnerships, contractual governance[119] and regulation, the greatest degree of trust is promoted through an emphasis on the social aspects of relationships, which result in the development of relational capital and environmental stability (Ireland and Webb, 2007, p. 494). High levels of relational capital and integration are characteristic of mature alliances and are key factors in the achievement of financial performance (Soderberg and Bengtsson, 2010).

**Perception management.**

Trust and relational capital are essential for the development of loyalty towards the SC and the avoidance of defections from the SC's collective objectives. Defections can be regarded to occur from

[119] A common method of contractual governance is "non-performance" clauses (Swink and Zsidisin, 2006, p. 4226).

behaviour that is motivated by self-interest, which includes the accessing of benefits without making a contribution towards them, claiming excessive benefits, the leveraging of critical paths and bottlenecks and the use of partner resources outside of the SC (McCarter and Northcraft, 2007, pp. 501-502). Furthermore, defection can occur from the shirking of responsibilities (Swink and Zsidisin, 2006, p. 4224). The investment in long-term supplier relationships and the achievement of financial performance is rooted in the selection of appropriate suppliers and the suppliers' commitment to the relationship (Hines, 1996; Carr and Pearson, 1999). Whilst financial metrics and strategic intent provide insight into the capability and motivation of a prospective supplier, the potential of the supplier to commit to a relationship is best understood from the social perspective of the supplier's cultural norms and values (Cannon *et al*. 2010, p. 517). Here, the candidate argues that the management of the perceptions of SC partners toward the SC is an important activity that maintains perceptions within the SC that are congruent with the SC's collective objectives. A key perception to manage is freedom from the fear of exploitation, which may lead to defensive behaviour within the SC (McCarter and Northcraft, 2007, p. 507). SCI benefits from the prevention of opportunism through relational governance, which is facilitated by the formation of perceptions toward the SC that are conducive to collective commitment (Zhao *et al*., 2008) and a common SC identity (Ireland and Webb, 2007, p. 494). Perception management entails the mediation of perceived relative power, which can arise from asymmetry in interdependency (Vijayasarathy, 2010, p. 500), strategic options (Narasimhan *et al*., 2009, p. 375), pricing information (Corbett *et al*., 2004) and the scarcity, concentration, criticality, allocation and control of resources (Mahapatra *et al*., 2010, p. 539). Relational governance can be formalised by implanting a system of distributive justice that is coherent with the sanctioned relational norms and values of the SC, which has the outcome of legitimising and promoting positive perceptions towards collective behaviour (Narasimhan *et al*., 2008, p. 28). A system of distributive justice is best affected through the joint creation of rewards and sanctions by the SC partners (McCarter and Northcraft, 2007).

**Design control.**

The integration of suppliers into new product development by downstream customers can gain access to external expertise (Petersen *et al*., 2005, p. 383), which can result in improved performance for the SC (Song and Di Bendetto, 2008, p. 15). The technical exchange between compatible cultures can be effective in the creation of structural embeddedness and the leveraging of synergies from complementary capabilities. The implications from the assignment of design responsibility and intellectual property ownership are expounded in Section 8.3.3 (d) Supply chain continuum of this dissertation.

**Management systems.**

An array of management systems have emerged that are specific to SCI, which are available commonly as software applications that can reside on a SC intranet. SCI management systems comprise typically databases for codification, optimisation, confidential data exchange and the accounting of relational transactions. Examples include Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Customer Relationship Management (CRM), Supplier Relationship Management (SRM), Knowledge Management (KM), Electronic Data Interchange (EDI), Vendor Managed Inventory (VMI) and Supply Chain Optimisation (SCO) (Wu, 2003, p. 1370; Das *et al*., 2006, pp. 564-566; Bayraktar *et al*., 2007, pp. 853-854; Hendricks *et al*., 2007, p. 80). The adoption of software based SCI management systems is characteristic of mature SCs and can be considered to signify a collective understanding of their perceived usefulness (Autry *et al*., 2010, p. 532).

**Logisitics.**

Ohno's vision of eliminating overproduction culminates ultimately in the elimination of warehouses. The significance of Ohno's vision to SC partners is that LM SCI demands JIT supply from upstream suppliers to downstream customers within a value stream

The candidate argues that the responsibility for the management of inventory and logistics is transferred down a LM value chain, which creates the need for extensive cooperation and synchronisation between SC partners in order to maintain efficient production flow. The candidate contends that inventory and logistics management within a SC can act as a tool for SCI and behavioural control.

The management of inventory and logistics within a SC has branched into several sub-themes in the literature for SCI, which include logistics information systems (Ketikidis *et al*., 2008), the management and selection of third-party logistics providers (Jayaram and Tan, 2010), product recovery mechanisms (Francas and Minner, 2009), the bullwhip effect from the amplification of variation in customer orders down the SC (Balan *et al*., 2009), strategic capacity allocation (Li *et al*., 2009), the optimisation of inventory levels (Keren, 2009), inventory risk sharing (Lai *et al*., 2009), supply outsourcing and the development of a portfolio of suppliers (Yue *et al*., 2010), environmental greening of the SC (Linton *et al*., 2007; Zhu *et al*., 2008) and the development of risk management strategies (Narasimhan and Talluri, 2009).

**Mutual hostages.**

The management of perceptions throughout the SC and the implementation of SC management systems can combine to create "mutual hostages", where opportunistic behaviour by a SC partner comes at a high economic cost to the opportunist and the whole SC (Ireland and Webb, 2007, p. 485).

#### 8.3.3 (d) SUPPLY CHAIN CONTINUUM.

Das *et al*. investigated the issue of what is the optimal level of SCI within the contexts of exploration and exploitation. According to Das *et al*. (2006, p. 568): “There would come a point when the gains from integration are completely offset by the costs of integration”. Das *et al*. argue that exploitative SCI manifests in dysfunctionalities that impact exploration and can be regarded as a cost of SCI (Das *et al*., 2006).

An issue that requires resolution is how to balance the degree of integration within a SC in order to affect exploration and exploitation. The candidate contends that the analytical framework defined in Figure 7 and the hypotheses developed in Chapter 6 of this dissertation explain the contextual conditions that guide the degree of supply chain integration.

**Intellectual capital and strategic divergence.**

According to Lockstrom *et al*. (2010, p. 241): “Strategic relationships are formed as a function of the business impact of the commodity to be sourced and the level of complexity of the supply market”. Here, the candidate argues that the strategic incentives to integrate within a SC are moderated by the potential to leverage intellectual capital according to contextual conditions. *E.g.* the sourcing of a generic component within a mature technological paradigm may have little business impact whilst the sourcing of a complex and novel technology may have a high business impact.

The candidate contends that the issue of who owns and can leverage intellectual capital within a SC is critical to SCI.

***White-box, grey-box and black-box design.***

Petersen *et al*. investigated the issue of how a supplier’s degree of responsibility in product design affects the financial performance of an integrated SC. A supplier’s degree of design responsibility was characterised according to the accepted terminology of white, grey and black-box design. White-box design is where the downstream customer retains design responsibility and consults its upstream supplier(s) as required. Grey-box design entails formalised co-development of a design with a joint limitation of responsibilities between downstream customer and upstream supplier(s). Black-box design is where an upstream supplier has design responsibility and supplies its downstream customer according to a performance specification (Petersen *et al*., 2005, p. 378). Petersen *et al*. found that the co-formulation of business objectives in an integrated SC with grey-box suppliers had a positive effect on financial performance whilst the co-formulation of business objectives with black-box suppliers had a negative effect on financial performance, which remained unexplained in the research (Petersen *et al*., 2005, pp. 384-385).

The candidate argues that grey-box suppliers gain more from collaboration with their downstream customers whilst black-box suppliers can gain more from the exploitation of their downstream customers. Furthermore, black-box relationships are typical of novel and complex innovation because the relationship indicates that is not feasible for the customer of a black-box supplier to achieve the innovation through its own capabilities.

***Leverage through intellectual capital.***

Black-box relationships are rare in integrated highly SCs for two key reasons. Firstly, the downstream customer must allow its black-box supplier to lead the technical agenda in order to achieve superior design outcomes (Lawson *et al*., 2008). Secondly, black-box relationships require a high degree of trust (Lockstrom *et al.*, 2010, p. 253). The candidate argues that black-box relationships are unconducive to SCI because they are characterised by an inherent tension between the need for the supplier's cooperation with the customer and the potential for the exploitation of the customer by the supplier through the leverage of intellectual capital. Whilst grey-box suppliers gain from strategic alliance with their customers, black-box suppliers gain by strategic divergence from their customers. Grey-box suppliers have an incentive to integrate with their customers because financial performance is coupled tightly to cooperative exploitation. Black-box suppliers have an incentive to remain disintegrated from their customers because they can exploit their intellectual capital according to an independent strategic agenda that assigns SCI lower priority. Swink and Mabert argue that the issue of intellectual capital ownership and leverage between a downstream customer and upstream supplier is fundamental. The downstream customer can licence intellectual capital to competing suppliers in order to promote price competition if it secures intellectual capital ownership and leverage. Conversely, the upstream supplier can promote price competition by selling the technology to the downstream customer's competitors if it secures intellectual capital ownership and leverage[120]. Furthermore, the upstream supplier can seek other applications for the technology outside of the existing paradigm or application if it secures intellectual capital ownership and leverage[121] (Swink and Mabert, 2000).

**Intellectual capital exploitation.**

Lockstrom *et al*. (2010, p. 241) explain that strategic SCI is guided by the level of mutual investments. The candidate has argued that suppliers of novel and complex innovation within a SC may have more

[120] The candidate contends that whilst the downstream customer may claim contractually intellectual capital it may not be able to exploit it because of insufficient knowhow of application. *I.e.* the ability to exploit the intellectual capital may be beyond the downstream customer's absorptive capacity.

[121] The candidate suggests that intellectual capital ownership and leverage by the upstream supplier can result in reluctance by the downstream customer to initiate post-production launch changes because of being charged a price premium. A price premium favours the upstream supplier because it creates stability and the potential to absorb productivity improvements without passing them on to the downstream customer. Automotive downstream customers apply typically contractual requirements for annual productivity improvements from their suppliers but these may be difficult to police because of shielded internal access to the upstream supplier. According to (Swink and Zsidisin, 2006, p. 4226) the issue of shielded internal access places the downstream customer in a weaker position and may be attributed unethically to the deliberate misrepresentation by the upstream supplier of their capabilities, market position and strategic intent.

to gain from dis-investment with the SC. The candidate contends that insights into exploratory innovation within a SC can be provided by investigating the incentives and consequences for exploratory suppliers within an exploitative SC.

***Exploratory incentive.***

Song and Di Benedetto researched the issue of a supplier's involvement in exploratory design and found that the downstream customer was reliant upon commitment from the upstream supplier and consistent long-term behaviour. However, upstream supplier's that had significant claim in intellectual capital may be tempted by opportunism through the exploitation of the weaker commercial position of its downstream customer (Song and Di Benedetto, 2008, p. 15). Moreover, Narasimhan *et al*. argue that a downstream customer's investment in the development of customer specific assets in a supplier could be exploited by the supplier if the supplier took a short-term approach to long-term profitability (Narasimhan *et al*., 2008, pp. 28-29).

***Exploratory consequences.***

SCs that require the development of complex and novel technology can benefit from the learning style of exploratory suppliers (Azadegan and Dooley, 2010, pp. 498-501). Whilst a SC may benefit from an exploratory supplier, the candidate argues that SCI can have negative consequences for exploratory suppliers. Arend and Wisner researched the issue of exploratory suppliers that engage in SCI and found that exploratory suppliers with strategic autonomy suffer general degradation in their financial performance and competitive position (Arend and Wisner, 2005, p. 428). Similarly, Colombo and Grilla found that the close relationship between the distinctive capabilities of technology based start-up firms and their founders vanished largely if downstream customers invested venture capital into the start-up enterprise (Colombo and Grilla, 2010, p. 624). Exploratory suppliers may also face other issues, which include the increased risk of unintended technological overspill and misappropriation, lost flexibility in setting short-term planning horizons and coercive forces from becoming an attractive acquisition target for downstream customers (Arend and Wisner, 2005, pp. 409-412). A supplier that has attractive intellectual capital can suffer pressure from its customers to sacrifice long-term market influence for short-term profit, which can arise from being a target of acquisition or being coerced to integrate with the SC in order to achieve stable supply (Horwitch and Theitart, 1987, p. 189).

The candidate contends that exploratory suppliers can bypass the tensions that arise from supply chain integration by exploiting their intellectual capital through autonomy.

**Intellectual capital and alliance structure.**

Farrell *et al*. modelled the characteristics of exploratory and exploitative alliances and their relationship to the alliance's structure. Exploitative alliances are regarded to be closed organisations where the value chain is closed to non-alliance partners. Exploitative alliances retain their intellectual capital for formally agreed use between alliance partners in order to enhance their capabilities (Farrell *et al*., 1998). Closed organisations consist typically of tiered suppliers that are integrated vertically (Kamath and Liker, 1994, p. 158; Hines, 1996, p. 3). Exploratory alliances are regarded to be open organisations that are driven by the development of intellectual capital that can be exploited in the general market. The intellectual capital generated by exploratory alliances is protected typically by patents *etc*. Open organisations have the lowest level of integration and contractual governance with their partners and have low levels of familiarity, commitment and trust (Farrell *et al*., 1998). Feller *et al*. argue that closed organisations engage in SCI whilst open organisations remain disintegrated in order to exploit their intellectual capital (Feller *et al*., 2006, pp. 178-188). The characteristics of exploratory and exploitative alliances that reflect the candidate's arguments are summarised in Table 45. The contextual conditions for SCI as a technological paradigm ages are shown in Table 46.

***Table 45: Characteristics of exploratory and exploitative alliances. Source: Candidate's design.***

| **ALLIANCE CHARACTERISTIC** | **EXPLORATORY FOCUS** | **EXPLOITATIVE FOCUS** |
|---|---|---|
| Structure. | **Open organisation.**<br><br>Small to medium enterprises.<br>Low familiarity, commitment and collaborative experience tending to loose networks. Intellectual capital protected by patents *etc.* | **Closed organisation.**<br><br>Large, highly integrated supply chains with strong customer focus.<br>Partners have democratic stake with complementary knowledge and capabilities. |
| Maturity. | Immature: novel and complex knowledge. | Mature: tried and trusted experience. |
| Dominant innovation object | Product first, process second. | Process first, product second. |
| Dominant innovation strategy. | Transformational and radical innovation. | Continuous improvement. |
| Relational strength, trust, commitment and importance. | Low. | High. |
| Knowledge creation strategy. | Low motivation to share knowledge and collaborate on research.<br>Openness to external information.<br>Low internalisation of lessons learned. | Shared synergy from complementary experience and knowledge bases through collaboration. Sharing facilitated by trust and contractual governance. |

***Table 46: Competitive advantage from supply chain integration according to the maturation of a technological paradigm. Source: Candidate's design.***

| Phase of maturation for a technological paradigm. | **EMERGENCE** | **CONSOLIDATION AND GROWTH** | **MATURITY AND DECLINE** |
|---|---|---|---|
| Benefit from competing through Supply Chain Integration. | Counterproductive initially then tending to minimal benefit. | Increasingly important with scope for rapid gains. | Fundamentally important but tending to diminishing returns. |

**Decoupling point.**

A decoupling point within a SC represents where pull-production ends (Gosling and Naim, 2009, p. 743). Moreover, a decoupling point can be regarded to signify a point where the downstream customer does not consider it necessary to modify the behaviour of the upstream supplier, which allows the downstream customer to engage in inventory buffering and multiple sourcing (Zsidisin and Ellram, 2003, p. 23).

The candidate argues that decoupling points can be used to delineate between technology-push and customer-pull in a SC through the manipulation of buffers.

**Migration from disintegration to integration.**

The candidate submits that the explore-exploit continuum for Supply Chain Integration can be represented by a migration from process **disintegration** to process **integration**, which allows an enterprise to secure first-mover advantages through a new technological paradigm and then exploit the new paradigm through supply chain integration. Table 47 summarises the candidate's submission.

*Table 47: Explore-exploit continuum for Supply Chain Integration.*
*Source: Candidate's design.*

| FOCUS | DISINTEGRATION (exploration) | MIGRATION <---> | INTEGRATION (exploitation) |
|---|---|---|---|
| **Boardroom strategy** | | | |
| **STRATEGY** | KEEP EXPLORATION OPEN. PROTECT INTELLECTUAL CAPITAL. | POSITION ENTERPRISE AS INDUSTRY NUB AND GATEKEEPER. | CREATE AND EXPLOIT SUPPLY CHAIN AS PARENT ORGANISATION. |
| **FINANCIAL MINDSET** | *"Start-up capitalisation will pay off long-term"* | *"Chase profit only after securing market"* | *"Reap rewards"* |
| **MANUFACTURING PARADIGM** | Craftsmanship. | Mass production. | Lean manufacturing. |
| **Shopfloor tactics** | | | |
| **CULTURAL INVESTMENT** | Self autonomy. Purchase standard inventory where possible. Co-opt technological suppliers. Stay small, flexible and uncommitted.<br><br>Develop intellectual capital in-house. | Contract supply through competitive bidding, based on cost and quality.<br><br>Parent organisation first, supplier second.<br><br>Consult suppliers as required. | Non-adversarial.<br><br>Development of relational capital. Trust, commitment, cooperation, collaboration, partnership, mutual problem solving, lessons learned, benefit, reward and future. |

| | | | |
|---|---|---|---|
| | Protect intellectual capital through patents *etc.* | Foster complementary goods. | SC first, parent organisation second.<br><br>Invest in, develop, and learn from suppliers. |
| **BUFFERING TACTIC** | Time. | Inventory. | Capacity. |
| **DECOUPLING POINT LOCATION** | Research and development office. | Within internal manufacturing operations (between assembly and manufacturing). | None: seamless conduit. |
| **DESIGN RELATIONSHIP** *From perspective of downstream customer.* | White-box. | White-box. | Grey-box. |
| **DESIGN RELATIONSHIP** *From perspective of upstream supplier.* | Black-box. | White-box. | Grey-box. |
| **ENABLING MECHANISMS** | Purchasing. | **Hidden plant.**<br><br>Network externalities.<br><br>Competitive bidding.<br><br>Push production.<br><br>Economies of scale.<br><br>Warehousing. WIP stock.<br><br>Quality management systems and certification. PPAP. | **Insidious plant.**<br><br>Exclusive, long-term contracts.<br><br>Agreed operational governance.<br><br>High capital asset interdependence.<br><br>Value stream mapping (synchronised flow).<br><br>Systemic integration and codification tools: ERP, EDI, SCM, CRM, SCO, KM *etc.*<br><br>Integrated logistics through JIT, *heijunka*, *kanban* and VMI.<br><br>Mutually agreed performance metrics.<br><br>Perception management. |

### 8.4 PRODUCT DEVELOPMENT.

Product development comprises the core processes of project management, intellectual capital management, risk management (and decision making) and design for manufacture and assembly. Here, the candidate examines individually the potential of each process to best support exploration and exploitation.

### 8.4.1 Project management.

The candidate contends that the process of project management within a technological paradigm can be encapsulated by the migration from invention to innovation. Innovation theory provides an accepted distinction between invention and innovation. An invention is something new whereas an innovation is the successful commercialisation of an invention. An invention can be an idea without practical use or commercial success whereas an innovation must meet a market need and be viable financially (Killen, 2005b).

#### 8.4.1 (a) PROJECT MANAGEMENT FUNCTION.

Project Management (PM) facilitates the organisation and coordination of resources for New Product Development (NPD). PM leverages structural, human and relational assets for the development of intellectual capital through "the application of knowledge, skills, tools and techniques to project activities to meet the project requirements" (Gray and Larson, 2003, p. 571). PM as a discipline can be regarded to comprise unique management processes (Turner, 1993, pp. 9-10).

#### 8.4.1 (b) PROJECT MANAGEMENT AS A STRATEGY.

The candidate argues that project management provides a structured approach to new product development in order to deal with the ambiguity and uncertainty that arises from the generation of new technologies.

**Ambiguity and uncertainty.**

Ambiguity in NPD arises from differing interpretations of the same information and uncertainty in NPD arises from lacking information (Brun and Saetre, 2009, p. 25). The design of novel products can result in ambiguity from the interpretation of the product and the validity and reliability of the information about the product, which in turn can generate ambiguity about the market conditions, NPD process and resources required (Brun *et al*., 2009, p. 75). Uncertainty from lacking information can lead to faulty management decisions (Browning, 2010, p. 331). Furthermore, uncertainty from lacking information can affect NPD timeliness and decision making because of differing perceptions of appropriate behaviour and task priority (Bendoly and Swink, 2007, p. 618). Conversely, extraneous information can slow or mislead decision making through inundation (Browning, 2010, p. 331). NPD can be regarded to be a problem solving and knowledge accumulation process where progress depends upon the generation of timely and effective information in order to reduce ambiguity and uncertainty (Mu *et al*., 2009, pp. 176-177). NPD can be regarded to be a process that is predicated on the assumption that questions can be asked and clear answers can be achieved (Brun *et al*., 2009, p. 65). Whilst ambiguity and uncertainty are inherent early in NPD, project clarity must be achieved before the market launch of a product in order to achieve an efficient outcome (Brun and Saetre, 2009, pp. 31-33). Project clarity is a fundamental antecedent of efficient NPD whereas product newness and complexity induce errors and delay (Chen *et al*., 2010, p. 28).

The candidate draws an analogy between NPD and *kanban* in that efficient NPD flow relies upon the right information, in the right amount, at the right location and at the right time.

**8.4.1 (c) CORE ENABLING METHODS AND TOOLS.**

PM manipulates the composition of its human resources and employs procedural tools. NPD may also use creativity provoking activities in order to stimulate innovation.

**Groups, individuals and teams.**

NPD can be executed through individuals, groups or teams where a group is two or more people that are brought together for a discrete purpose and a team is a group that has worked together sufficiently to have developed a degree of unitary behaviour (Parkin, 1996, p. 135).

**Process mapping.**

PM relies typically on tools that map visually the NPD process (Browning, 2010, pp. 317-319). NPD mapping tools include work breakdown structures, budgets, resource and cost schedules, Gantt charts, PERT simulation, baselines and critical paths (Gray and Larson, 2003), project constraints (Goldratt, 1997) and textual narration (Browning, 2010).

The candidate argues that new product development mapping tools mirror the lean manufacturing concept of value stream mapping.

**Phased product development systems.**

PDCA, APQP and 6 sigma can be regarded to be phased development systems where the progress of development is regulated through a schedule of process inputs, process outputs and performance metrics. The application of phased product development systems can be regarded to be a generic approach to NPD (Ulrich and Eppinger, 2000, Chapter 2). Phased development systems have typically formal approval of individual phases whereby a phase is not regarded to be completed until all the objectives of that phase have been achieved. The formal approval of individual phases can be regarded to be a stage-gate™ system of go/kill decision points (Cooper, 1990). A key feature of phased product development systems is that whilst the approval of individual phases is sequential the execution of the project tasks is parallel, which can provide a compression of overall project timing through efficiency with superior performance outcomes (Ranky, 1994, pp. 21-23). Parallel task execution is expedited through the use of cross-functional teamwork, which is characterised by development teams that are composed of multiple functions who report collectively to a single project manager. Furthermore, cross-functional teams are co-located typically and are dedicated to the project for the life of the project (Ulrich and Eppinger, 2000, Chapter 2). Concurrent product development through cross-functional teamwork is the approach adopted by Toyota, which is known generally by the concepts of *obeya* (single room with no partitions) and *mieruka* (clear and common visualisation of project objectives) (Morgan and Liker, 2006; Takeuchi *et al*., 2008). Toyota argues that cross-functionality facilitates efficient communication that is complemented by diverse input, which results in superior innovation outcomes (Takeuchi *et al*., 2008). Contrastingly, sequential NPD engages specialised and segregated functional departments that have their own management hierarchy and departmental agendas. Sequential NPD is characterised by the consultation of specialist functions as required by a project manager. A hybrid of the parallel and sequential approaches to NPD is a matrix structure, which assigns functional representatives from individual departments to a dedicated NPD project and project manager. Whilst the functional representatives are dedicated for the life of the project and are required to follow the directions of their assigned project managers, the functional representatives remain responsible to their departmental management (Ulrich and Eppinger, 2000, Chapter 2). A limitation with the matrix structure is the potential for a conflict in objectives, which can arise from the functional representatives being responsible to both project managers and their departmental management. A lightweight matrix structure is one where the departmental management has greater power over its functional representatives whilst a heavyweight matrix structure is one where the project managers have greater power over the functional representatives (Hayes *et al*., 1988 cited in Ulrich and Eppinger, 2000, Chapter 2).

**Team building.**

PM has multiple theories of team development[122] because of the importance of cross-functional teamwork in phased product development systems. The removal of team members from the psychological safety of their functional departments and their placement into a dedicated cross-functional team environment can provide multiple benefits, which include the efficient concurrency of activity and a multi-faceted, dimensionally complete approach to problem solving (Post *et al*., 2009, p. 22). The theories of team development encompass the issues of team selection[123], leadership style[124], conflict resolution[125], rejuvenation[126] and remedies for various pathologies that may emerge[127].

[122] *E.g.* 5 stage developmental model: forming-storming-norming-performing-adjourning (Tuchman, 1965 cited in Gray and Larson, 2003, p. 351) and punctuated equilibrium model (Gersick, 1988 cited in Gray and Larson, 2003, p. 353).

[123] *E.g.* skills and personality profiling.

[124] *E.g.* de Jong and Hartog (2007, p. 49) identified 13 leadership behaviours that influence innovation and NPD execution.

[125] *E.g.* avoidance, diffusion, confrontation (Pinto and Kharbanda, 1995, p. 52).

[126] *E.g.* new rituals, rekindled hope and commitment through pep talks, friendly challenge, self-reflection, expert consultation and critique, obstacle analysis and removal, outdoor experiences (Gray and Larson, 2003, pp. 370-371).

[127] *E.g.* bureaucratic bypass syndrome, entrepreneur's disease, team infatuation, going native (Gray and Larson, 2003, pp. 374-375), groupthink (Janis, 1971), polarised opinions (Parkin, 1996, pp. 143-144) and blind conformity through group pressure (Asch, 1956 cited in Parkin, 1996, p. 142).

**Creativity provocation activities.**

Project managers may employ creativity provoking activities[128] in order to stimulate inventive solutions in NPD. The creative ideas that are generated can be filtered and combined through structured screening methods[129].

**8.4.1 (d) PROJECT MANAGEMENT CONTINUUM.**

The candidate argues in this section that invention in its pure form is organic and indeterminate whilst innovation in its pure form is a structured process.

**Exploitative project management.**

The cross-functional integration of product development teams and their PM experience are key factors in efficient NPD (Swink *et al*., 2006).

***Project management efficiency.***

Enterprises that have efficient PM are regarded to have common defining characteristics. Efficient PM is expedited through cross-functional teamwork and concurrent NPD processes that have formalised NPD procedures and decision making rules, which promote collaborative learning (Chen *et al*., 2010, p. 17). Furthermore, efficient NPD and collaborative learning are strengthened by the dedication of PM teams to NPD projects for the life of the project and the integration of customers and suppliers into NPD (Chen *et al*., 2010, pp. 28-29). Team-based collaborative learning can foster a shared mindset (Post *et al*., 2009, p. 15) and social connectivity (Thomas-Hunt *et al*., 2003, p. 464). Enterprises that have efficient PM have commonly high levels of codification (Bendoly *et al*., 2009, p. 313) with dedicated PM information systems that support the planning, execution and control of NPD projects (Cleland, 1999, Chapter 12). Furthermore, PM information systems allow the experience, lessons and tacit knowledge learned in NPD projects to be codified and disseminated within and between project teams (Goffin *et al*., 2010). The reduction of ambiguity and uncertainty in PM through the reliability of information and team behaviour can lead to more predictable NPD outcomes, which allows the application of diagnostic PM control systems with quantitative performance metrics (Chiesa *et al*., 2009). Furthermore, a reduction of ambiguity and uncertainty has positive benefits throughout the entire SC because the integration of suppliers and customers into NPD promotes greater compatibility and technological readiness between upstream and downstream SC partners (Clausing and Holmes, 2010, p. 52).

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[128] *E.g.* fluency stimulation (storyboarding, brainwriting, excursion sessions), pattern breaking and shake-up exercises (Thomas, 1993, pp. 33-36), brainstorming (Osborn, 1938 cited in Thomas, 1993, p. 34) and TRIZ (Altshuller, 1984 cited in Mann, 2002, p. 86).

[129] *E.g.* Matrix based selection through rating and ranking (Ulrich and Eppinger, 2000, Chapter 7).

*Derivative design.*

The candidate argues that project management in exploitative enterprises can be characterised by efficient new product development that centres upon derivative designs of mature technological paradigms.

**Exploratory project management.**

The candidate argues in this section that whilst PM can provide efficiency through the reduction of ambiguity and uncertainty in NPD, there may be a reduction in inventive capability, which accords with the productivity and innovator's dilemmas. Furthermore, a potential reduction in inventive capability can arise from a shift in the perception of what constitutes proactive sources of creativity, which accords with the proactivity dilemma.

*Sources of creativity.*

Creativity may arise from random events (McDermott, 1999, p. 639), accidents, cognition, association or "divine" inspiration (Henry, 1991 cited in von Stamm, 2003, pp. 7-8). Creativity is influenced by personality, learning style, education and training, personal motivation and environment conditions (Brennan and Dooley, 2005). However, creativity may also have an underlying process (*e.g.* preparation-incubation-illumination-verification) (Wallas, 1926 cited in von Stamm, 2003, p. 10). Creativity within the context of an enterprise can be stimulated by knowledge management processes (Brennan and Dooley, 2005), PM leadership style (de Jong and Hartog, 2007), reward systems (Cotterman *et al*., 2009, p. 20) and the enterprise's overall creativity capability (Schilling, 2005, pp. 16-17).

*Creativity in an exploitative project management context.*

Collaborative NPD results typically in knowledge creation and learning outcomes that tend towards competency enhancing incremental innovation (Feller *et al*., 2006, p. 187). Here, the candidate argues that efficient PM can have potential negative consequences for an enterprise's inventive capability. Efficient PM can have the negative consequence that NPD team members are selected on the basis of their collaborative performance rather than their individual performance (Feng *et al*., 2010, p. 660), which can result in a focus on social connectivity and cohesion that tends to exclude divergence (Thomas-Hunt *et al*., 2003, pp. 473-474). High social connectivity and cohesiveness can affect the selection of future NPD projects and the evaluation of potential NPD solutions because of the development of behavioural-based project controls, which are biased towards the selection of potential projects and solutions that are consistent with enterprise's culture, codes and values (Chiesa *et al*., 2009, p. 438). Cohesive behavioural-based project controls influence the way opinions are elicited and aggregated during the selection of potential NPD projects and the evaluation of proposed NPD solutions (Ozer, 2005). Furthermore, cohesiveness can act to prevent the tension and political manoeuvring of PM actors within and across projects that can arise from the ambiguity, uncertainty, disruptive events and crises that are inherent in exploration (Edwards, 2007, pp. 402-403). Exploitative PM can tend towards risk aversion (Mu *et al*., 2009, p. 170), which results typically in cautious decisions and designs (Rose-Anderssen *et al*., 2005, p. 1104). Risk aversion and a cautious approach to NPD can become amplified as a technological paradigm ages because exploitative PM becomes increasingly sensitive to trade-offs between project timeliness, performance and costs as an enterprise approaches the technology's productivity frontier (Swink *et al*., 2006, p. 542). Risk aversion may also be amplified by a compounding costliness of errors, which is implied in the intensity of communication and overlapping of activity that arises from operating at the productivity frontier (Lin *et al*., 2009). An extreme negative consequence of exploitative PM is that NPD can become mechanistic and devoid of creativity (Rose-Anderssen *et al*., 2005, p. 1103). Here, the candidate argues that the loss of creativity from exploitative PM can affect an entire enterprise. Creativity at the NPD team level can suffer from socially connected team members evaluating unfavourably the contribution of social isolates who may provide valuable and unique contributions (Thomas-Hunt *et al*., 2003, p. 474). The cohesive mindset of socially connected team members can dampen the likelihood of contrary or divergent knowledge and opinions being shared (Post *et al*., 2009, p. 15). PM that does not promote risk taking, pioneering or entrepreneurship results typically in a lacklustre innovation climate, which is perceived to devalue individual creativity (de Visser *et al*., 2010, p. 296). Furthermore, formalised, codified and logic based NPD can lead to less diversity and challenge, which may result in an apathetic attitude that does not question existing assumptions and beliefs (Post *et al*., 2009, p. 22). Moreover, an enterprise that engages in intense exploitation can become devoid of effective search and screening mechanisms for new product ideas, which can accommodate radical or transformational ideas at an enterprise level (Jespersen, 2007, pp. 463-464). Whilst collaboration has a positive effect on NPD efficiency throughout an enterprise's SC, an exploitative enterprise may suffer from a lack of strategic vision and dynamic innovation capability (Johnson and Filippini, 2010, p. 29). An enterprise that is experienced in exploitative PM can be impeded in its ability to recognise viable opportunities and partnerships that are outside of the enterprise's existing SC (Hoang and Rothaermel, 2010, p. 753). Finally, exploitative enterprises may reward formally PM teams that recommend the early abandonment of NPD projects that are risky, expensive and without immediate market uptake (Cotterman *et al*., 2009).

***Antecedents of exploratory PM.***

Transformational and radical NPD projects become increasingly disparate with an enterprise's architecture, processes, financial and developmental timetables and performance metrics as the enterprise tends to a dominant exploitative footing (McDermott, 1999, p. 641). Furthermore, cross-functional teamwork is unconducive to exploratory PM for three key reasons. Firstly, cross-functionality tends to increase the number of perspectives, opinions and options that must be considered and managed, which can detract from the establishment of high-order concepts (Post *et* *al.*, 2009, p. 15). Secondly, cross-functionality may increase superfluous input that is centred upon fine details, which can impede the exploration of high-order concepts (Chen *et al.*, 2010, p. 28). Thirdly, the ambiguity and uncertainty that is inherent in exploratory PM can inflame dysfunctional interpersonal conflict between team members, which may arise from competing functional agendas and priorities (Janssen *et al.*, 2004, p. 133). According to Zollo and Winter, cross-functional input and debate is not effective until design concepts have declined in abstraction (Zollo and Winter, 2002, p. 344). Exploratory PM benefits from flexible and socially based management control rather than the rigid procedural and diagnostic control of exploitative PM (Chiesa *et al.*, 2009). Exploratory PM is fostered by environments where ambiguity and uncertainty are useful contributors to the facilitation of novelty, flexibility and invention rather than being precursors of dysfunctional interpersonal conflict through competing functional agendas and priorities (Brun and Saetre, 2009, p. 31). Transformational and radical PM is best achieved through informal networks (McDermott, 1999, p. 642), which can be characterised by design-led sequential problem solving and functional consultation as required (Chen *et al.*, 2010, pp. 20-21).

**Migration from invention to innovation.**

The candidate submits that the explore-exploit continuum for Project Management can be represented by a migration from the **invention** of a product to the **innovation** of the product, which allows an enterprise to secure first-mover advantages through a new technological paradigm and then exploit the new paradigm through the development of derivatives within the paradigm. Table 48 summarises the candidate's submission.

***Table 48: Explore-exploit continuum for Project Management.***
***Source: Candidate's design.***

| FOCUS | INVENTION (exploration) | MIGRATION <---> | INNOVATION (exploitation) |
|---|---|---|---|
| **Boardroom strategy** | | | |
| **STRATEGY** | INVENTION IN AMBIGUITY AND UNCERTAINTY. | DEVELOPMENT WITH TOLERABLE AMBIGUITY AND UNCERTAINTY. | INNOVATION WITH AMBIGUITY AND UNCERTAINTY ELIMINATION. |
| **Shopfloor tactics** | | | |
| **LEADERSHIP STYLE** (de Jong and Hartog, 2007, p. 49). | *Organic and indeterminate.* | Innovative role model. Intellectually stimulating. Visionary. Innovation recognition and support. Informal knowledge diffusion. | Consultative. Delegative, task assignment. Monitoring. Providing metrics based feedback, rewards, resources. |

| | | | |
|---|---|---|---|
| **PM MINDSET** | *Organic and indeterminate.* | Divergent thinking. | Convergent thinking. |
| **NPD MINDSET** (Kirton,1976, p. 623).<br>-----<br>(Extracts from Table 14: Adopter Categories in this dissertation). | Undisciplined. Tangential approach from unsuspecting angles. Challenges assumptions, problems, rules, customs, and culture. Disregardful of practicality, soundness, processes, accepted theory, group cohesion, cooperation. High self-confidence, retaining certitude in face of opposition. Control taking in unstructured situation, crisis, with problem/solution discovery and manipulation. Delegative of routine tasks. Dynamic catalyst for radical/transformational change.<br>-----<br>Technology enthusiasts, gatekeepers. Adventurous. Comfortable with complexity and uncertainty. Cost unimportant. Creative. Risk taker. Experimenter. Entrepreneurial. Uncontrolling. Receptive. Open-minded. | Moderation of inventive mindset towards innovative mindset. | Precise, reliable, methodical, efficient prudent, disciplined and conforming. Concerned with resolving problems, rather than finding them. Problem reduction through improvement rather than wholesale change. Dislike for uncertainty and ambiguity. Sound, safe and dependable, providing order, continuity and stability. Turns processes into goals. Maintains accuracy in detail over long period. High internal authority for process knowledge within discrete domain within embedded structure. Compliant, cooperative, cohesive, cautious, relationship sensitive, providing safe base against disruption.<br>-----<br>Conservative. Price sensitive, demanding. Sceptical, critical. Responsive to peer pressure. Preference for structures, certainty, intense producer/consumer relationship. Dislikes waste. Worried about financial risk. Expects high performance Resistant to radical change. |
| **PM STRUCTURE** | *Organic and indeterminate.* | Loose networks. Centralised control. Design-led innovation process with discretionary functional exclusion. Functional departments with high expertise. Group based consultation through serial problem solving. Design function retains NPD control, with other functional departments integrating after design firmed, tending to lightweight matrix organisation with tentative team development. Performance metrics with quantitative bias. | Cross-functional, co-located, dedicated team reporting to single project manager. Horizontal organisation with high structural integration between information systems, customers and suppliers. Phased, concurrent NPD with phases culminated in executive sign-off. Knowledge codification. Performance metrics with quantitative bias.<br><br>*obeya* |

| | | | |
|---|---|---|---|
| **PM OBJECT** | Competency destroying disruptive technologies. | Dominant design. | Competency enhancing derivative designs. |
| **ENABLING TOOLS** | *Organic and indeterminate.* | Informal centralised progress reviews as required. Small group decision making. Broad scope. Floating financial and performance metrics. | Project management information systems, codification, Gantt, PERT, TOC, WBS, Budgeting, Baselining, Critical path. Structured concept screening. Phased management review. Teambuilding, conflict resolution, pathology correction. Fluency and pattern breaking exercises. TRIZ, Brainstorming.<br><br>*mieruka* |

### 8.4.2 Intellectual capital management.

The candidate contends that the management of intellectual capital within a technological paradigm can be encapsulated by the migration from the invention a disruptive technological paradigm to the innovation of the disruptive paradigm.

#### 8.4.2 (a) INTELLECTUAL CAPITAL FUNCTION.

Intellectual Capital (IC) comprises the three elements of human, structural and relational capital. Human capital is the tacit knowledge and skills that are acquired by individuals as capabilities or know-how. Structural capital includes non-human repositories of knowledge such as codification, physical structures, processes and various forms of Intellectual Property (IP). Relational capital is the knowledge embedded in the relationships within a parent enterprise and its SC (Chang *et al*., 2008, p. 300). IC management stimulates innovation and is a key contributor to economic strength in developed nations (Killen, 2005a). The legal protection of IC promotes competition, honest trade practices and creativity (WIPO World IP Office, 2005).

The candidate argues that the composition of an enterprise's intellectual capital reflects its architecture, dominant innovation mechanism and object.

#### 8.4.2 (b) INTELLECTUAL CAPITAL MANAGEMENT AS A STRATEGY.

**Exploratory intellectual capital management.**

The candidate argues that exploratory IC management centres on the generation and protection of disruptive technologies. The denial of a coveted technology to competitors is a powerful commercial position for an enterprise to hold. Technological denial can be achieved through the legal protection of IP, which affords an enterprise a time and competency buffer against external replication of the protected technology. Two key strategies for protecting technologies are the erection of patent fences and the cultivation of cognitive capitalism.

***Patent fences.***

Germeraad argues that patents are an effective strategy for the legal protection of disruptive IP. Patents can be exploited through the erection of patent fences, which are characterised by the establishment of a founding patent and the development of follow-on patents that are linked to the founding patent through legal citation. Follow-on patents can build upon and extend the founding patent to form a patent fence that protects legally the commercially important features of the technology for the longest possible time. The maximum benefit from patent fences is derived from a crafted carefully parent patent, which provides the maximum scope for claims of legal enforceability and quality of litigative outcomes. Furthermore, the enterprise must develop continually follow-on patents in order to remain ahead of rival patents (Germeraad, 2010, pp. 10-15).

***Cognitive capitalism.***

The candidate argues that enterprises with disruptive technologies can protect and leverage their IC through the development of their internal capabilities in order to achieve self-reliance. Cohen and Levinthal explain that an enterprise's exploratory absorptive capacity is developed through self-reliance, which positions the enterprise for future exploitation from both internal and external sources and allows the enterprise to respond rapidly to competitor threats (Cohen and Levinthal, 1990, p. 147). Furthermore, the candidate argues that through self-reliance the enterprise can position itself strategically as the gatekeeper and nub for the disruptive technology's industry as the regulatory or *de facto* industry standard. The enterprise may then benefit further by embedding the disruptive technology within other technological paradigms and industries through liscensing[130]. Moreover, the candidate argues that self-reliance has the further benefits of avoiding ownership disputes with development partners and minimising the overspill of IC. Cui *et al*. argue that strategically important technologies must be owned exclusively and shielded from unauthorised use (Cui *et al*., 2009, p. 61). The sharing of IC with alliance partners may develop into a dispute over who owns the IC versus who has the right to use the IC (Mehlman *et al*., 2010, pp. 56-60). The exclusion of external partners minimises the overspill of IC and the threat of opportunism from external partners (Holcomb and Hitt, 2007, p. 471). The overspill of IC can also occur through information sharing during negotiations with potential alliance partners, which subsequently do not develop into an alliance (Mehlman *et al*., 2010, pp. 56-60). Finally, overspill can be limited through the development of cognitive capitalism by restricting the movement of human capital, which can be affected through

[130] Permission to use IP can be granted through licensing agreements (WIPO World IP Office, 2005).

the retention of key personnel through incentive schemes and the regulation of information disclosure[131] (Magnani, 2009, p. 16).

Whilst it may not be possible for an enterprise to avoid interaction with an external alliance, the candidate argues that interaction should limited to consultation. Freel and de Jong explain that consultative alliances are characterised by weak and uncommitted relationships where partners are sought for inspiration, advice, feedback and opportunity and not a source of joint problem solving or information sharing (Freel and de Jong, 2009, p. 881). The candidate argues finally that suppliers of strategic IC to an enterprise should become a target of acquisition or co-optation.

**Exploitative intellectual capital management.**

The candidate argues that exploitative IC management centres upon the enhancement of an enterprise's competencies through the development of human, structural and relational capital. Germeraad argues that patent fences lose their effectiveness as a disruptive technological paradigm's industry tends to commodification, which occurs from patent crowding and litigious testing. Furthermore, patents tend towards incremental improvement as the paradigm ages and becomes generic industry knowledge through reverse engineering. According to Germeraad, the protection of IP in the exploitative phase of a technological trajectory centres upon the development of an enterprise's trademark, trade secrets and derivative industrial designs[132] (Germeraad, 2010, pp. 15-18). Here, the candidate argues that an exploitative enterprise has more to gain from competency enhancement than the generation of IP in a mature paradigm. Cui *et al*. argue that exploitative IC management focuses on manufacturability and systems compatibility (Cui *et al*., 2009). The development of systemic compatibility platforms in a mature technological paradigm is a valuable source of IC (Schilling, 2003, pp. 29-30). Here, the candidate argues that IC management in exploitative enterprises becomes increasingly problematic outside of stable alliances. Minshall *et al*. argue that IC management can be problematic when an incumbent enterprise engages in the development of IC with a start-up enterprise. The start-up enterprise may be reluctant to divulge IC to the disparately powerful incumbent for fear of exploitation. Conversely, the incumbent may fear brand abuse by the start-up through their promotion of the alliance with the incumbent to other potential customers in order to gain credibility (Minshall *et al*., 2010). The management of IC by exploitative incumbents can benefit from stable and committed relationships with their alliance partners through the mutual pursuit of competency enhancement (Freel and de Jong, 2009). The candidate has argued in this dissertation that stable and committed relationships are characterised

131 Non-disclosure agreements (NDAs) are a common method for the regulation of intellectual capital (Mehlman *et al*., 2010, p. 57).

132 A trademark is a distinctive sign that is associated with an enterprise. Trade secrets include know-how and confidential or proprietary information. An industrial design is the ornamental or aesthetic aspect of a product (Killen, 2005a).

by structural and relational embeddedness, which engage in a grey-box approach to the development of IC.

#### 8.4.2 (c) CORE ENABLING METHODS AND TOOLS.

The core method of IC management is the protection of original contributions to prior-art. The protection of IC entails legal enforcement. The tools for IC protection can be classified as a patent, trademark, industrial design, copyright, circuit layout, trade secret, drawing, confidential information, specifications, trade name, insignia, know-how, design and laboratory journals, design calculations, email, document and contract *etc*. (Killen, 2005a).

#### 8.4.2 (d) INTELLECTUAL CAPITAL MANAGEMENT CONTINUUM.

**Migration from disruptive invention to market innovation.**

The candidate submits that the explore-exploit continuum for Intellectual Capital Management can be represented by a migration from the **invention** of a competency destroying technological paradigm to the **innovation** of the paradigm, which allows an enterprise to secure a buffer against competitors through protected intellectual property. A buffer against competitors from the denial of access to the disruptive technological paradigm allows the enterprise to exploit the paradigm by the enhancement of the enterprise's unique competencies through the development of human, structural and relational capital. Table 49 summarises the candidate's submission.

*Table 49: Explore-exploit continuum for Intellectual Capital Management.*
*Source: Candidate's design.*

| FOCUS | INVENTION (exploration) | MIGRATION <---> | INNOVATION (exploitation) |
|---|---|---|---|
| **Boardroom strategy** | | | |
| STRATEGY | CREATE COMPETENCY DESTROYING INVENTION. | BECOME INDUSTRY GATEKEEPER AND NUB. | IMPLEMENT COMPETENCY ENHANCING INNOVATION. |
| **Shopfloor tactics** | | | |
| IC MINDSET | *"Invent and protect".* | *"Invent and innovate".* | *"Innovate".* |
| IC TACTICS | Self-reliance.<br>Exploratory absorptive capacity development.<br>Overspill containment.<br>Patent fence at paradigm level. | Patent fence at architectural level.<br>High patent velocity.<br>White-box design. | Component patents.<br>Internally backward compatible, competitor incompatible system platforms.<br>Manufacturability. |

| | | | |
|---|---|---|---|
| | High patent velocity.<br>Create new “prior-art”.<br>Isolation, exclusion and denial of IP.<br>Litigation.<br>Cooptation.<br>Uncommitted relationships.<br>Trademark creation.<br>Non-disclosure agreements. | Establishment of actual or *de facto* industry standard (dominant design).<br>Strategic positioning as industry gatekeeper/nub and embedding IP in other paradigms/industries through licensing.<br>Process organisation and technology development.<br>Trademark development. | External innovation sourcing through grey-box design with non-disclosure agreements.<br>Contractual governance of supply chain.<br>Reverse engineering.<br>Benchmarking. Codification.<br>Process re-organisation and technology development.<br>Human capital development through know-how.<br>Trade secrets.<br>Derivative industrial designs.<br>Trademark enhancement. |
| **ENABLING METHODS** | Intellectual property and human capital. | Intellectual property, human capital and structural capital. | Human, structural and relational capital. |

#### 8.4.3 Risk management (and decision making).

The candidate contends that a risk management within a technological paradigm can be encapsulated by the migration from intuitive to rational decision making.

#### 8.4.3 (a) RISK MANAGEMENT (AND DECISION MAKING) FUNCTION.

According to Standards Australia (1999, Section 1.3, p. 4), Risk Management (RM) is: “the culture, processes and structures that are directed towards the effective management of potential opportunities and adverse effects”.

#### 8.4.3 (b) RISK MANAGEMENT (AND DECISION MAKING) AS A STRATEGY.

The candidate argues that risk management provides a structured approach to decision making in order to deal with the ambiguity and uncertainty that arises from the generation of new technologies. Ambiguity and uncertainty affect the outcomes of decision making, which has a direct impact on the sustainability of an enterprise. Whilst decision making may follow a logical process, the perception of potential hazards and opportunities and what constitutes data and facts are value laden constructs, which are influenced by the decision making environment.

**Facts, values and inference.**

Whilst facts symbolise objectivity, what constitutes and determines a fact has a value construct, which is encoded with the beliefs and experiences of the scientific community. Fischhoff argues that no scientific knowledge is culturally impervious and that what is posited as a fact and the method used for its validation is a political act. Furthermore, once facts are established as truth and are acquired socially then facts can in turn shape values (Fischhoff, 1989). Moreover, when resources do not permit the timely scientific acquisition and validation of knowledge that is required for decision making, the gaps in knowledge are bridged through inference and belief (Adams, 1995, p. 49).

**Hazard and opportunity perception.**

The perception of and response to potential hazards and opportunities by individuals and groups has a behavioural element[133] that is similar to how data and facts are encoded with values. The variation in perception by individuals and groups implies that consensus is unlikely on what constitutes hazards and opportunities. According to Whittaker, the decision to instigate RM is a politically laden act because it entails inevitably negotiation, bargaining and power manoeuvring (Whittaker, 1991, p. 16). Contemporary RM processes attempt to overcome the political aspects of RM by establishing firstly a RM context that is agreed by key stakeholders in the RM process[134] (*e.g.* Standards Australia, 1999).

**Decision making.**

The candidate argues in this section that rational decision making is confined to special circumstances.

***Rational analysis.***

Rational analysis can be regarded as a scientific system of decision making, which has a reliance on quantitative factual knowledge and corresponds generally to the cause and effect approach[135] of PDCA (Parkin, 1996, p. 55). An issue with rational analysis is that it conforms rarely to the observed behaviour of decision makers (Parkin, 1996, p. 71). Jungermann explains that rational decision making is problematic for two reasons. Firstly, rational decision making is biased by how problems are represented and perceived, defective information searches and personal motivations. Secondly, compromised decisions that result in a reasonable outcome can be argued to be rational behaviour because they optimise the emotional and cognitive costs of making the decision (Jungermann, 1983, pp. 63-86). *E.g.* A consumer wants a blue car but purchases a white car because it is the only colour present in a showroom. The consumer’s decision from the perspective of rational analysis could be argued to be flawed because blue would provide greater satisfaction to the consumer than white. However, by taking into account that white was regarded to be a satisfactory colour by the consumer and the acquisition of a blue car would entail a significant search or delay, then the consumer’s decision could be framed as rational. Whilst the consumer wants blue, the effort required to acquire a blue car was not justified, which resulted in a reasonable decision. The behavioural problems that rational analysis suffers from can be addressed significantly through the codification and control of knowledge and decision making processes, which can oblige explicit and consistent outcomes

133 Various theories have been submitted to explain the attitudes and beliefs that shape the perceptions of hazards and opportunities. *E.g.* economic, psychological, social and cultural theories (Renn, 1992), knowledge and political theories (Wildavsky and Dake, 1990, pp. 42-44).

134 Whilst the establishment of an agreed RM context can ostensibly never be free of value and politics it can formalise the strategic positions and objectives of the key stakeholders and a RM process.

135 A typical system for rational decision making is problem recognition/goal identification/option generation/information search/assessment/choice/post-decision evaluation (Jaccard *et al*., 1989 cited in Parkin, 1996, pp. 118-119).

(Parkin, 2000; Zollo and Winter, 2002). Furthermore, Hogarth argues that rational consistency can be improved through adaptive learning. Whilst an individual's behavioural biases may be initially dysfunctional, they may be improved through continuous feedback and adjustment (Hogarth, 1981).

***Quasi-rationality.***

The behavioural variation in how potential hazards and opportunities are perceived and what constitutes data and facts can be explained through social judgement theory, which can be represented by Brunswik's lens model of judgement. Brunswik contended that an imperfect transmission of data occurred through an individual's senses and mind in opportunistic or problematic situations because of an individual's unique bias towards the cues that are selected and the weighting that is attributed to them. Imperfect transmission of data between individuals produces differing cognitions, which results in differing judgements. Moreover, an individual's cognition varies according to external influences and feedback over time (Brunswik, 1952). Judgement can be regarded to be a dynamic quality that is dependent upon an individual's unique biases and the environmental stimuli that prevail at the time of judgement. According to Cooksey (1996, p. 142): "not only is there inherent uncertainty within the environment and ecology of a decision task, there is also inherent uncertainty within an individual as to how cue information should be utilised to guide judgemental responses in that ecology".

Parkin explains that an outcome from social judgement theory is that the prevailing nature of decision making is quasi-rational, which is characterised by a compromise between the extremes of intuition and rational analysis (Parkin, 1996, Chapter 7). Table 50 details the characteristics, assumptions and biasing influences of intuitive, quasi-rational and rational decision making.

***Table 50: Characteristics, assumptions and biasing influences of intuitive, quasi-rational and rational decision making.***
***Source: Candidate's design based on*** Parkin (1996).

| INTUITION | QUASI-RATIONALITY | RATIONAL ANALYSIS |
|---|---|---|
| | *Characteristics.* | |
| Logical rules unavailable.<br>Rapid information processing.<br>Simultaneous cue use.<br>Procedurally untraceable.<br>High outcome confidence.<br>Errors normally distributed.<br>Inconsistent/low cognitive control.<br>Low cognitive effort.<br>Can cause interpersonal conflict.<br>Pictorial/non-verbal cue reliance.<br>Cue data/events stored in memory.<br>Resistant to new cues.<br>Vicarious functioning.<br>Weight average organisation.<br>Perceptual cue evaluation<br>(Cooksey, 1995 cited in Parkin, 1996, p. 106). | Blend/compromise. | Logical rules available and used.<br>Slow information processing.<br>Sequential cue use.<br>Procedurally traceable.<br>High process confidence.<br>Errors few, but large.<br>Consistent, high cognitive control.<br>High cognitive effort.<br>Tends to avoid conflict.<br>Quantitative cue reliance.<br>Organisation principles stored in memory.<br>Responsive to new cues.<br>Concrete organisation functioning.<br>Task specific organisation.<br>Measured cue evaluation<br>(Cooksey, 1995 cited in Parkin, 1996, p. 106). |

| | | |
|---|---|---|
| *Assumptions.* | | |
| Nested in biasing influences. | Blend/compromise. | Goals explicitly defined/static/aligned with values.<br>Decision precedes action.<br>Optimal solution possible<br>Alternatives/consequences/likelihood known or can be determined.<br>Data relevant/accurate/fixed/stored.<br>Measurements/preferences consistent.<br>Time/ funds available proportionate to complexity.<br>Decision has purpose: not symbolic/political.<br>Intent not random/experimental.<br>Spontaneity, fortuitous decision ignored.<br>Alternatives equally assessed/values separated from science.<br>Positivist beliefs and behaviour. |
| *Biasing influences.* | | |
| Cue selection influenced by:<br>Easily retrieved data.<br>Selective bias from role/expertise.<br>Valuing information from past experience and trusted colleagues.<br>Information format.<br>Wishful thinking.<br>"Glowing solution"<br>Rejecting contradictions to dominant cluster.<br>(Hogarth, 1987 cited in Parkin, 1996, pp. 109-110).<br>Personal values, organisational/cultural norms.<br>(March, 1994 cited in Parkin, 1996, pp. 110-112).<br>Judgement biased by:<br>How problem is framed.<br>Overconfidence/false confidence.<br>Value conflict.<br>Sunk costs.<br>Stress, fear of failure, fatigue.<br>Influence from others and pressure to conform.<br>Personality.<br>(Hogarth, 1987; Mullen and Roth, 1991cited in Parkin, 1996, pp. 112-115). | Blend/compromise. | Believing independent events are dependent (gambler's fallacy).<br>Overestimate probability of familiar events/underestimate unfamiliar.<br>Self-deception in imagining scenarios.<br>Ignoring differences in population size.<br>Basing judgement on too small/large sample size.<br>Ignore unseen failures and focus on success.<br>Correlation bias/illusions.<br>Underestimation of complex events.<br>(Hogarth, 1987; Mullen and Roth, 1991cited in Parkin, 1996, pp. 65-66). |

**Individual versus group decisions.**

The decision making task may be centred on an individual, group or team, which impacts the decision making strategy and outcome.

***Individual decisions.***

Parkin suggests that pure rationality in individuals is affected when intuition, creativity and expertise have been "displaced by codification" (Parkin, 2000, p. 60). Whilst codification is a prescriptive approach to decision making, Beach offers a descriptive approach to individual decision making called image theory. Beach argues that individuals enframe decision situations with knowledge structures that give the situation meaning and constrain the decision making process through images of the decision maker's values, goals and plans. Potential decisions are tested for compatibility with the decision maker's images and a decision that is highly compatible may be adopted readily (Beach, 1993, Chapter 7). Furthermore, Klein explains that experiential expertise can affect recognition-primed decision making, which is characterised by rehearsed judgement and the evocation of pre-determined decisions (Klein, 1993 cited in Parkin, 1996, p. 128). However, the candidate argues that decisions based on experiential expertise may be detrimental to exploration. According to de Bono, the commitment to familiar meanings that have proved usefulness in the past can be strong (de Bono, 1971, p. 61).

***Group decisions.***

Bloomfield and Best contend that the issue of how power is exercised is central to understanding the decision making process from a social perspective (Bloomfield and Best, 1992, p. 534). According to Fischer (1990, p. 282), decisions are primary access points to power and act as “arenas for political conflict and bargaining”. Group decisions within the context of an enterprise are influenced typically by multiple social mechanisms with varying degrees of influence (Vroom and Jago, 1974, p. 743). Access to group decisions allows coalition and interest groups to exert influence, which has the effect of provoking compromised decisions (Fischer, 1990, p. 283). Group decisions can be regarded to have a powerful political dimension where the power struggle between the actors in decision making transforms continuously the identities and influence of the actors (Callon, 1987, pp. 99-100).

***Team decisions.***

The candidate explained in Chapter 7 of this dissertation that constructive teamwork promotes the development of a shared mental model. Whilst shared mental models can be regarded as a positive asset in appropriate contextual conditions, intense teamwork can incite pathologies that result in dysfunctional decision making. Janis explained the condition called groupthink, which biased decisions in favour of boosting morale at the expense of critical thinking. Groupthink is characterised by powerful group norms that avoid harsh judgements of the team leader and team members. Extreme manifestations of groupthink are loyalty to dysfunctional policies and shared illusions (Janis, 1971). Similarly, Barker argued that empowered work teams can develop concertive control, which imposed self-constraining mechanisms upon the team (Barker, 1993). However, Manz and Neck argue that the onset of groupthink can be checked by a concept called teamthink, which challenges a team to be aware of its internal dialogue, beliefs and assumptions (Manz and Neck, 1995).

**8.4.3 (c) CORE ENABLING METHODS AND TOOLS.**

The candidate argues that exploitative risk management and decision making is centred upon prescriptive methods and tools that employ quantitative rational analysis whilst exploratory risk management recognises the role of intuition and quasi-rationality in risk management and decision making.

**Exploitative context.**

***Probability analysis.***

RM and decision making can be managed through quantitative tools, which determine the likelihood of potential events that result in a positive or negative outcome. Likelihood can be expressed as a direct probability (*e.g.* 85%) or a relative probability (*e.g.* medium). Risk is determined as a function of the frequency of an event and the severity of its consequences (Standards Australia, 1999, Section 1.3). Common probability based tools include fault, event and decision trees, HAZOP, FMEA, human reliability analysis (Standards Australia, 1998) and various multi-attribute rating tools and rules (Parkin, 1996, Chapter 5). An important feature of quantitative RM and decision making tools is that they rely on the availability of relevant data, which is provided typically through codification.

***Residual risk.***

Contemporary RM recognises that there may be a pragmatic limit to how much risk can be avoided, eliminated or ameliorated. According to Standards Australia (1999, p. 3): residual risk is "the remaining level of risk after risk treatment measures have been taken". Quantitative RM tools allow residual risk to be codified as a benchmark. *E.g.* automotive PPAP approval quantifies residual risk in FMEA, which provides an agreement between customer and supplier of acceptable residual risk and a platform for ongoing risk treatment.

***Power based network enrolment.***

The candidate argues that power based network enrolment can be used by stable enterprises in order to control disseminated decision making and promote *kaizen*. Power based network enrolment translates problems and opportunities into a framework that aligns the interests of network actors with the interests of the enterprise in order to provide incentive. The decisions and actions of the network actors can be controlled by creating obligatory passage points that must be passed in order to enact a decision (Parkin, 1996, Chapters 11-12). The candidate argues that LM value streams can be regarded as networks and *kanban* can be regarded as an obligatory passage point. The empowerment of employees frames problems and opportunities as being in the actor's domain, which provides an incentive for *kaizen*.

**Exploratory context.**

***Intuition and quasi-rationality.***

The candidate argues that intuition and quasi-rationality facilitate exploration. Wallsten contends that in an environment of ambiguity and uncertainty linguistically expressed risk is more effective than rational analysis based on quantitative probabilities because language can better convey the context and meaning of the risk assessment (Wallsten, 1990 cited in Rennie, 1994). Whilst intuition and quasi-rationality suffer inherently from incomplete knowledge and imperfect transmission, the judgements made occur rarely in complete ignorance. Butler and Loomes explain that intuitive and quasi-rational judgements are made through lateral connections to prior experiences and indirect information sources (Butler and Loomes, 1997, p. 136). Burke and Miller argue that intuition and quasi-rationality may foster exploration for four key reasons. Firstly, the dynamic nature of intuition and quasi-rationality may lead to improved decision outcomes by balancing rational analysis and keeping it in perspective. Secondly, they allow easier navigation through and diffusion of political agendas. Thirdly, their flexibility helps maintain a focus on strategic imperatives in an uncertain environment. Fourthly, they facilitate personal development and positive risk taking (Burke and Miller, 1999). Moreover, Trailer and Morgan contend that high levels of intuitive knowledge can be developed that allow the application of consistent intuitive decision policies (Trailer and Morgan, 2004, p. 46).

***Emotional intelligence.***

Prentice explained a leadership style that was based on tactful communication and mentoring of subordinates, which sparked work interest, corrected flawed perceptions and made tolerable the frustrations of subordination (Prentice, 1961). Goleman related Prentice's leadership style to financial performance and developed a leadership model that was founded on emotional intelligence (EI), which allowed a leader to manage effectively themselves and their relationships through diverse and contextually specific leadership styles. The key traits of EI are self-awareness, self-regulation, passion and drive, empathy and social skills (Goleman, 1998; 2000). Earley and Mosakowski argue that the concept of EI can be extended to include cultural intelligence, which may be used in the management of groups, departments, enterprises, nationalities *etc*. (Earley and Mosakowski, 2004). EI is prevalent amongst top managers in enterprising environments that are characterised by the need for persuasion and leadership (van der Zee and Wabeke, 2004). Moreover, high EI can be effective for the management of radical and transformation change within enterprises by establishing positive relationships between an individual's personality and their attitude towards change (Vakola *et al*., 2004, p. 102). Here, the candidate contends that EI and cultural intelligence accommodate intuition and quasi-rationality, which can foster and spur exploration.

***Concentrated decision locus.***

The candidate contends that exploratory decisions are facilitated by a concentrated decision locus at an executive level, which accords with the observations and arguments that were presented in Chapters 5 and 6 of this dissertation.

#### 8.4.3 (d) RISK MANAGEMENT (AND DECISION MAKING) CONTINUUM.

The candidate has argued that the exploitative approach to RM and decision making is structured and quantifiable. Hogarth contends that incremental decision making can result in "cognitive myopia", which impedes imagination and creativity (Hogarth, 1981, p. 213). Here, the candidate argues that an emphasis on scientific approach to RM and decision making is unconducive to exploration for four reasons. Firstly, an emphasis on prescription may result in confusion between the decision making process and the objective of the decision. *E.g.* According to ASEA-AutoCRC, Toyota will praise an employee if the sanctioned decision making process was adhered to regardless of a negative outcome. Conversely, an employee will be admonished if a positive outcome was achieved in the absence of the sanctioned process (ASEA-AutoCRC, 2010). Secondly, exploration poses significant challenges to a team based approach to decision making because team members are tuned to respond typically to cues that are appropriate to their area of expertise (Post *et al*., 2009, p. 14). Thirdly, the effectiveness of codified knowledge is sensitive highly to the timing of codification. Premature codification can result in generalisation whilst late codification can record flawed perceptions of causal relationships (Zollo and Winter, 2002, p. 349). Fourthly, the proactivity dilemma asserts that an exploitative enterprise will populate itself with employees that have a propensity towards exploitation. According to Jabri, employees may have a propensity towards a logical approach to problem solving or an intuitive approach to problem solving (Jabri, 1991, pp. 982-983). The candidate argues that rational analysis in an exploratory context requires moderation. According to Schreier (1959, p. 111): "It is the task of scientific management to make the process of decision making more rational and to remove some of the guess-and-gamble". Where scientific analysis is hampered by ambiguity and uncertainty, Burke and Miller argue that the recognition and application of intuition is more appropriate. Moreover, an enterprise must understand how its culture explicitly or implicitly discourages the use of intuition in order to remove barriers that block the creative benefits from intuition (Burke and Miller, 1999, p. 96).

**Migration from intuitive to rational decision making.**

The candidate submits that the explore-exploit continuum for Risk Management can be represented by a migration from **intuitive** to **rational** decision making. Table 51 summarises the candidate's submission.

*Table 51: Explore-exploit continuum for Risk Management (and Decision Making). Source: Candidate's design.*

| FOCUS | INTUITION (exploration) | QUASI-RATIONALITY | RATIONAL ANALYSIS (exploitation) |
|---|---|---|---|
| **Boardroom strategy** | | | |
| **STRATEGY** | SEIZE OPPORTUNTIES.<br><br>CONTINGENT RISK TREATMENT. | GAIN EXPERIENCE.<br><br>RISK MITIGATION AND TRANSFER. | CODIFY LEARNING.<br><br>RISK ELIMINATION AND AVOIDANCE. |
| **Shopfloor tactics** | | | |
| **CORE METHODS AND TOOLS** | Concentrated decision locus.<br>Individual or group decisions at executive level.<br>Creative adaption.<br>Emotional intelligence.<br>Intuition barrier removal.<br>Ignore progress limiting risk through strategic contingencies. | Semi-concentrated decision locus.<br>Group decisions at executive level with consultation as required from lower management levels.<br>Development of intuition based policies.<br>Image based trajectories.<br>Recognition priming.<br>Commence risk transfer to functional departments, suppliers *etc.* for aggregated mitigation. | Disseminated decision locus.<br>Integrated team decisions at lower management levels.<br>Reasoned choice.<br>Probability analysis.<br>Power based network enrolment.<br>Enterprise wide codification.<br>Collective SC risk elimination and avoidance. |

## 8.4.4 Design For Manufacture and Assembly.

The candidate contends that Design For Manufacture and Assembly (DFMA) within a technological paradigm can be encapsulated by the migration from Design For Novelty (DFN) at the pre-dominant design phase to DFMA at the post-dominant design phase.

### 8.4.4 (a) DFMA FUNCTION.

DFMA places manufacturability into the forefront of product development.

### 8.4.4 (b) DFMA AS A STRATEGY.

The influence of manufacturing specialists in NPD can enhance significantly manufacturing efficiency (Swink, 1999; Bajaj *et al*., 2004). Manufacturing representatives in cross-functional NPD can provide timely information on issues related to manufacturing integration, resources and capabilities (Swink and Song, 2007, p. 206). Furthermore, manufacturing representation in NPD can eliminate mis-communication of assumptions between product and process designs (Browning and Heath, 2009, p. 34). DFMA facilitates efficient manufacturing through standardised design (Schonberger, 2007, p. 410), reduced processing (Boothroyd and Dewhurst, 1988 cited in Schonberger, 2007, p. 410), lower part counts (Browning and Heath, 2009, p. 26), modularity (Hallgren and Olhager, 2009, p. 754) and *poka yoke* features (Browning and Heath, 2009, p. 32). Product designs that strive to minimise part counts in order to eliminate or rationalise manufacturing processes can be regarded to be lean designs (Munro and Associates, 1996).

**8.4.4 (c) CORE ENABLING METHODS AND TOOLS.**

DFMA may be utilised in a holistic method such as manufacturing representation in NPD or through prescriptive and codified tools. A common prescriptive tool is the Boothroyd-Dewhurst system (Schonberger, 2007, p. 410).

**8.4.4 (d) DFMA CONTINUUM.**

Clark explained that process capabilities can alter the characteristics of product designs (Clark, 1985, p. 248). Here, the candidate contends that the influence of manufacturing considerations in exploratory design may constrain creativity and novelty. However, the formation of a dominant design catalyses process organisation, which benefits from the influence of manufacturing considerations. McDermott argues that when the producer's and consumer's experiences with a new paradigm are taking formation the best performance outcomes occur through the consultation of manufacturing generalists in product development rather that the permanent inclusion of manufacturing specialists (McDermott, pp. 639-643). Swink and Song suggest that the inclusion of manufacturing specialists in an exploratory context may constrain creativity, which can occur from an incomplete vision of the enterprise's strategic imperatives and viewing high-order concepts through a lens that is oriented towards details and existing capabilities (Swink and Song, 2007, p. 205). The candidate argues that the consultation of manufacturing generalists can facilitate the migration from exploratory DFN to exploitative DFMA through integrated, cross-functional teamwork.

**Migration from DFN to DFMA.**

The candidate submits that the explore-exploit continuum for Design for Manufacture and Assembly can be represented by a migration from **design for novelty** to **design for manufacture and assembly**, which allows the exploration of novel concepts and the creation of intellectual property that can be exploited through design for manufacturing and assembly after the formation of a dominant design. Table 52 summarises the candidate's submission.

*Table 52: Explore-exploit continuum for Design for Manufacture and Assembly. Source: Candidate's design.*

| FOCUS | DFN (exploration) | MIGRATION <---> | DFMA (exploitation) |
|---|---|---|---|
| **Boardroom strategy** | | | |
| **STRATEGY** | CREATE INTELLECTUAL PROPERTY. | ORGANISE PROCESSES WHEN DOMINANT DESIGN FORMED. | OPTIMISE PROCESSES. |
| **FINANCIAL MINDSET** | *"Cost of doing business"* | *"Cost-down opportunities"* | *"Profit optimisation"* |
| **Shopfloor tactics** | | | |
| **CORE METHODS AND TOOLS** | Design for novelty.<br><br>Ignore or place low priority on manufacturing considerations. | Consult manufacturing generalists as required. | DFMA through integrated, cross-functional teamwork.<br><br>Boothroyd-Dewhurst.<br><br>Lean product design. |

**8.5 STRATEGIC PLANNING.**

Strategic planning comprises the core processes of customer management and financial evaluation. Here, the candidate examines individually the potential of each process to best support exploration and exploitation.

**8.5.1 Customer management.**

The candidate contends that the process of customer management within a technological paradigm can be encapsulated by the creation and installation of new consumer needs and the reaction to the development of the new consumer needs.

**8.5.1 (a) CUSTOMER MANAGEMENT FUNCTION.**

Customer management entails the management of an enterprise's relationships with its customers, which falls generally under the umbrella of customer focus. According to Australian Quality Council (1994b, p. 3-10) a customer focussed enterprise provides: "products and services that are relevant to the customers requirements". An enterprise's customer focus is reflected in how customer needs are integrated into product design and the enterprise's innovation strategy (Australian Quality Awards Foundation Limited, 1995, pp. 21-22).

**8.5.1 (b) CUSTOMER MANAGEMENT AS A STRATEGY.**

Consumers that are exposed to a new technological paradigm develop consumption capabilities through the use of the technology in a co-evolutionary learning process with the technology's producers. Consumers that are skilled in the use a technology have the capability to understand and articulate their needs (von Tunzelmann and Wang, 2007, pp. 195-196). A customer focus allows an enterprise to develop a relationship with customers through the satisfaction of their needs (Australian Quality Council, 1994b).

**8.5.1 (c) CORE ENABLING METHODS AND TOOLS.**

The candidate argues that marketing is the key method for customer management, which acts as a conduit between consumers and producers. Furthermore, exploratory marketing entails the generation and projection of signals into the marketplace and the reading of responses whilst exploitative marketing entails reading market signals and feeding back responses.

**Exploitative marketing.**

According to Griffin (1996, p. 155): "information derived from unknowledgeable customers is at best inaccurate and at worst is an irrelevant fantasy. To act upon it is extremely risky". The issue of accurate customer intelligence has spawned a raft of marketing tools that include surveys, interviews, consumer site visits, focus groups, intermediaries, associations, employee intelligence, industry consultants and researchers, consumer groups, direct observation, databases, customer embedding in NPD (Gober, 1994, Chapter II), market segmentation analysis (Australian Quality Council, 1994, p. 3-33), consumer brainstorming, long-term non-intrusive *in situ* embedding and observation, hosted webpages for consumer suggestions (Cooper and Edgett, 2008, p. 51), sales feedback (Cotterman *et al*., 2009, p. 18), product tear-down analysis (Lee, C-T., 2010) and customer perception analysis (LoSardo and Rossi, 1993, p. 56). A marketing representative in cross-functional NPD can impact positively the exploitation of customer needs for three key reasons. Firstly, through the communication of explicit customer needs and product performance evaluations (Langley *et al*., 2009, p. 7). Secondly, through the defence of customer relationships against deterioration (Homburg *et al*., 2009a, pp. 71-72). Thirdly, by increased profitability through enhanced product performance and a reduction in design re-work and delays in product launch (Bajaj *et al*., 2004, p. 428).

**Exploratory marketing.**

Sandberg argues that exploratory marketing suffers inherently from ambiguity and uncertainty because of the difficulty in securing reliable market intelligence. Ambiguity and uncertainty can make exploration difficult to justify financially and in an exploratory context exploitative marketing tools are often misleading (Sandberg, 2007, p. 253). According to Langley *et al*. the marketing of exploratory technologies encounters typically three problems. Firstly, exploratory technologies often change the structure of markets and thereby invalidate expert opinions and data that is founded upon the consumption patterns that existed before the technology was released. Whilst it may be possible to extrapolate data based on similar technologies, the process of diffusion is nested in human behaviour, which creates the difficult task of factoring behavioural subtleties into the data in order to make meaningful comparisons[136]. Secondly, exploratory technologies appeal initially to specific adopter categories that must be identified in order to have a greater understanding of the technology's diffusion potential. Thirdly, exploratory technologies are met typically with resistance from users of incumbent technologies. Accordingly, resistant consumers must be identified in order to moderate the evaluation of prototypes and the market reaction towards the new technology. Langley *et al*. argue that exploratory marketing can benefit from the identification of adopters that are most likely to stimulate imitative behaviour, which facilitates the diffusion of the technology (Langley *et al*., 2009, pp. 6-7). Exploratory marketing can be regarded to influence and change actively consumer behaviour in order to create markets that do not exist currently (Sandberg, 2007, p. 253). Exploratory marketing in exploitative enterprises may also face the challenge of resource competition with manufacturing operations because of the ambiguity and uncertainty associated with exploration, which can dampen an enterprise's exploratory commitment (Hess and Lucas, 2004).

**Lead users.**

Technology-push contrasts customer-pull in that technology-push is based on the proactive anticipation of new market opportunities whereas customer-pull is based on the reaction to consumer needs in an established market (Sandberg, 2007, p. 263). A key method for forecasting technology-push market opportunities is the identification of lead users[137] who have needs that will become general in the marketplace but face them well in advance of others. Lead users have needs that are not met by existing technologies and are positioned to benefit significantly from a solution to their needs, which often incites self-experimentation and the development of intellectual capital (Urban and von Hippel, 1988, pp. 569-570). Lead users precede and are different to early adopters. Lead users engage actively in the development of a solution to their needs whilst early adopters are the first to purchase the solution if it is innovated (Thomson and Nimgade, 2001, p. 510). Heiskanen *et al*. explain that in addition to intimating market opportunities and providing intellectual capital, lead users can assist in the promotion of a new technology, which may be beneficial in helping overcome resistance to change that can occur when incumbent technologies are threatened with disruption. Resistance to change can arise not only from the threat of technological disruption but from a threat to social connectivity. Disruptive technologies have the potential to affect social

[136] Behavioural based issues are long known to be a significant factor in comparative analysis (*e.g.* Schreier, 1959, pp. 116-117).

[137] Examples of products that were generated by lead users include hair conditioner, mountain bikes and surfboards (Thomson and Nimgade, 2001, p. 510).

relationships by changing the way people interact and their self-autonomy. The effect of disruptive technologies on social relationships can range from impacting a single family to the extreme of threatening global[138] stability (Heiskanen *et al*., 2007, pp. 504-505). An individual's perception of the potential outcomes from a new technology can range from being positive or negative, which can stimulate proponents of the new technology and defenders of incumbent technologies (Haggman, 2009). *E.g.* Automobile Year (1982) explains that the reaction from the general public towards the automobile during its origin was often fear, derision and hatred. Morrison *et al*. suggest that lead users can play a vital role in the moderation of the threats from disruptive technologies because they provide an important and credible source of communication about the new technology (Morrison *et al*., 2004, p. 361). Moreover, the incorporation of lead users into product development can facilitate exploration (Clark, 1985). Here, the candidate argues that the co-optation of lead users into an enterprise can provide a powerful source of intellectual capital.

**Selection through absence.**

The candidate observed a novel means of combining the benefits of technology-push and customer-pull marketing in the hospitality industry, which the candidate believes may be applied generally. Saleh explains: prospective wine suppliers may push the introduction of new wines onto the wine list of a Cafe by lobbying for a trial period where new wines are supplied cheaply. The Cafe may adopt a candidate wine for a trial period and advertise it as a special or wine of the month *etc*. at a reduced price, which characterises modesty. The candidate wine is then withdrawn after a trial period and the customer-pull reaction to the wine's withdrawal is monitored. The subtlety of this approach is that not only do initial sales provide a measure of market attractiveness but positive inquiry after withdrawal indicates the wine was consumed for its character, rather than being "just a glass of modest priced wine". A successful candidate wine can then be adopted as a permanent wine list item at its full price (Saleh, 2010).

**Technological foresight through scenarios.**

Scenario techniques allow the exploration of disruptive technologies by projecting them into the future in order to provide foresight into the possible scenarios that may emerge. An advantage of scenario techniques is that assumptions and expectations can be projected to their extremes, which provides insight into the best-case and worst-case scenarios that may emerge (Drew, 2006).

**Intuition.**

Successful technological breakthroughs may be sparked by "gut feel" (McDermott, 1999, p. 639).

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[138] An example of how technologies can affect global stability can be found in the struggle between the Spanish conquistadors and native South Americans. The Spaniards came across vast South American empires that were devoid of the wheel in transport and metal weaponry, which are regarded to be technologies that forced the destabilisation of South American society.

#### 8.5.1 (d) CUSTOMER MANAGEMENT CONTINUUM.

The candidate contends that the customer-pull model of customer management is predicated on three assumptions about the needs of consumers. Firstly, consumers know what they need. Secondly, consumers can articulate their needs and producers can read them. Thirdly, the satisfaction of the consumer's needs should lead product development. However, Deming (1993, p. 7) observes: "Does the customer invent new product or service? The customer generates nothing". Here, the candidate argues that the customer-pull model is limited by the voice of the customer because it does not accommodate the possibility of influencing or changing the consumer's behaviour through the creation and installation of new needs. Deming (1993, p. 7) further contends: "The fact is that the customer expects only what you and your competitor have led him to expect. He is a rapid learner". The candidate argues that the technology-push approach and the customer-pull approach to marketing are valid according to appropriate contextual conditions, which are implied in the normal evolution of a technological paradigm. The candidate believes that the previously cited quotes by Deming reflect the technology-push approach to marketing, which may have been influenced by his experience and observations of the automobile paradigm. Deming was born in 1900 during the disruptive origin of the automobile paradigm and lived to become an engaged academic in the customer-pull era of the automobile paradigm. According to Deming (1993, p. 7): "No customer asked for an automobile. We have horses: what could be better? I can testify to that. No customer asked for pneumatic tyres. Tyres are made of rubber. It is silly to think of riding on air. The first pneumatic tyres in the United States were not good. The user had to carry with him rubber cement, plugs, and a pump, and know how to use them. I can testify to that".

**Migration from creation to reaction.**

The candidate submits that the explore-exploit continuum for Customer Management can be represented by a migration from the **creation** of new customer needs to a **reaction** to the installation of the new customer needs, which accords with the migration from technology-push to customer-pull through the normal development of a technological paradigm. Table 53 summarises the candidate's submission.

*Table 53: Explore-exploit continuum for Customer Management.*
*Source: Candidate's design.*

| FOCUS | CREATION (exploration) | MIGRATION <---> | REACTION (exploitation) |
|---|---|---|---|
| **Boardroom strategy** | | | |
| **STRATEGY** | CREATE NEW CUSTOMER NEEDS. | INSTALL NEEDS IN MAINSTREAM MARKET. | SATISFY INSTALLED NEEDS. |
| **Shopfloor tactics** | | | |
| **CULTURAL INVESTMENT** | *"Show, sell, teach and tell customers what they need. Explain what they are missing out on".* | *"Develop relationship with customers through greater contact".* | *"Ask customers what they need. Listen and react. The customer is always right".* |
| **ENABLING TOOLS** | Technology-push.<br><br>Generation and projection of market signals. Reading of responses.<br><br>Marketing aimed at influencing and changing consumer behaviour.<br><br>Lead user identification and co-optation. Lead user and innovator adopter market promotion.<br><br>Scenario analysis. Intuition.<br><br>Identification of innovator adopters who will stimulate imitative behaviour.<br><br>Identification of resistant consumers. | Establish distribution network, dealerships, customer contact points *etc.*<br><br>Promote and partner complementary network externalities. Maximise interaction, exposure and installed base.<br><br>Develop customer relationships. Embed need and relationship in customer lifestyle.<br><br>Selection through absence. | Customer-pull.<br><br>Reading of market signals. Feedback response.<br><br>Customer focus: benchmarking, satisfaction measurement, customer needs research and deployment.<br><br>Surveys, interviews, visits, focus groups, intermediaries, associations, employee intelligence, industry consultants/researchers, consumer groups, direct observation, databases, market segmentation *etc.*<br><br>Quality management tools: QFD, FMEA *etc.*<br><br>Marketing representation through integrated, cross-functional teamwork.<br><br>Defence of customer relationships. |

### 8.5.2 Financial evaluation.

The candidate contends that successful financial evaluation balances the exploitation of aging technological paradigms with the invention of new technologies in order to create a sustainable technological development portfolio.

#### 8.5.2 (a) FINANCIAL EVALUATION FUNCTION.

Financial evaluation can be regarded to be the process of determining potential invention and innovation opportunities and their subsequent justification and selection.

#### 8.5.2 (b) FINANCIAL EVALUATION AS A STRATEGY.

The candidate argues that the composition of an enterprise's technological development portfolio provides insights into the enterprise's technological strategy and its likelihood of ongoing sustainability, which is reflected in the external assessment of professional stock-market investors.

**The external perspective of professional investors.**

Van Wyk explains that the global association of investment professionals introduced in 2008 an assessment template, which judged the technological potency of enterprises. A key issue for investment professionals is the capability an enterprise has in invention and innovation, which is regarded to be the fundamental driver of the enterprise's profitability and sustainability. Technologically potent enterprises represent an attractive investment proposition whilst technologically impotent enterprises are unattractive. Technological potency is judged by an enterprise's capability in dynamic innovation, its procedures for technological renewal and the technological astuteness of executive management (Van Wyk, 2010).

The candidate argues that a sustainable enterprise offsets exploitation with exploration, which is characterised by a balanced technology development portfolio.

**Balanced portfolio.**

A key feature of enterprises with high innovation performance is the development of a balanced technological development portfolio, which incorporates the technology-push and customer-pull approaches to innovation (Cotterman *et al.*, 2009, p. 20). Balanced technological development portfolios address the issues of a technology's timing, risk and diffusion (Product Development Institute Incorporated, Cooper-Edgett, 2005), which are moderated by the technology's strategic importance and the capability of an enterprise to assert the technology (Cooper *et al.*, 2001). Balanced portfolios can be regarded to be an economic equilibrium between the exploratory approach of opportunism and exploitative approach of capitalisation (Terwiesch and Ulrich, 2008, p. 28).

**Dynamic portfolio management.**

The candidate argues that Schumpeter's waves of creative destruction and the saturation of technological paradigms through normal technological development imply that an enterprise's technological development portfolio is dynamic inherently.

**The value of a technological development portfolio.**

The candidate argues that the value of a technological development portfolio is reflected in the reference groups that an enterprise selects for benchmarking its market position, the valuation of customer capital and the methods used for the selection and justification of technological development projects.

The candidate argues that exploratory enterprises value their technological development portfolios differently to exploitative enterprises. An issue that requires resolution in order to develop a balanced portfolio is the accurate determination of a portfolio's value.

***Reference groups.***

Massini found that exploitative enterprises tended to benchmark their market position against enterprises that are similar to themselves, which was characterised by a tendency towards the population average. Exploratory enterprises tended to benchmark their market position against the top quartile of leading-edge enterprises (Massini *et al*., 2005, p. 1654). Here, the candidate argues that exploitative enterprises may over-value their technological development portfolios when they use homogenous reference groups because of a narrow frame of reference, which values highly conformity.

***Customer capital.***

Customer capital is the value that is embedded in customer relationships, which is reflected in repeat business, customer satisfaction, loyalty, mutual understanding and price sensitivity (Kannan and Aulbur, 2004, p. 390). Homburg *et al*. (2006) explain that the development of customer capital is a cumulative process and that customer judgements are evolving constantly (Homburg *et al*., 2006). Homburg *et al*. (2009a) argue that exploitative enterprises that adopt a defensive position towards the preservation of customer relationships may over-value the customer capital that is embedded in them. Customer relationships with high embedded capital in an exploitative context are perceived as being too important to lose and are valued highly. Furthermore, an exploitative enterprise may under-value the potential to take an offensive position in order to acquire new customers and develop new sources of customer capital (Homburg *et al*., 2009a).

***Project justification and selection.***

Exploratory enterprises may have difficulty in the establishment of quantifiable causality between the investment in a technology and its future revenue (Dissel *et al*., 2009, pp. 47-48). Furthermore, when market intelligence if lacking exploratory enterprises may use qualitative metrics in the assessment of the potential long-term benefits of a technology (Cooper *et al*., 2001, p. 81). Here, the candidate argues that exploitative enterprises value highly the use of quantifiable data and in doing so may over-value technological development projects that are quantified readily. Accordingly, an exploitative enterprise may under-value technological development projects that have an ambiguous or uncertain quantitative evaluation. According to Chiesa *et al*., the estimation of a technological asset based on quantitative analysis alone can be misleading because it may fail to take into account the qualitative factors that can add value to the technology (Chiesa *et al*., 2007).

**8.5.2 (c) CORE ENABLING METHODS AND TOOLS.**

The methods and tools for financial evaluation can be regarded to be those used to create and develop potential technological portfolios and those used for project justification and selection.

**Portfolio creation and development.**

***Market context.***

A technological development portfolio can be regarded to be an outcome from an enterprise's business plan, innovation strategy and market context (Terwiesch and Ulrich, 2008). Key tools for the determination of market context and the exploration of potential opportunities include the 6-forces model, strength-weaknesses-opportunities-strengths (SWOT) analysis, barriers to entry and switching cost analysis, distinctive competencies analysis, product differentiation analysis, market segmentation analysis (Dorf and Byers, 2005, pp. 78-90), value roadmapping (VRM) of potential value streams (Dissel *et al*., 2009, pp. 48-49) and the determination of productivity frontiers (state of best practice) (Porter, 1996, p. 62).

***Visual representation.***

Portfolios can be represented visually in various formats. The most common format is 2-dimensional[139], which comprises matrices, bubble charts, bar and pie charts. Typical evaluation metrics are risk/reward, success probability/reward, time to launch/NPV, strategic value/success probability, implementation ease/market attractiveness, market risk/technology risk, technology newness/market newness, strategic intent/market segment, customer value perception/enabling technology, internal impact/external impact, launch date/resource utilisation, cash flow/year, budget/project *etc*. (Cooper *et al*., 2001, Chapter 4).

***Dynamic analysis.***

Several methods may be used in order to foster a dynamic perspective towards the creation and development of technological development portfolios. A method for inciting exploration is to use heterogeneous reference groups in the benchmarking of current market position rather than homogenous reference groups (Massini *et al*., 2005, p. 1654). The identification of risks and opportunities in existing customer relationships can be determined through an analysis of the

[139] 3-axis portfolio formats exist and are typically software based (Cooper *et al*., 2001, pp. 80-81).

characteristics of stable and switching consumers (Homburg *et al*., 2009a, p. 86). The diffusion of a technology may be enhanced by the identification of consumer groups that provide maximum imitation potential and the identification and installation of mechanisms that disrupt competitor imitation (Langley *et al*., 2009). The exploration of risk hedging strategies such as diversification, investment in competitors with similar technologies or investment in competitors with the potential to disrupt or substitute the enterprise's technologies may provoke deeper contextual awareness and reveal unforseen opportunities (Luo *et al*., 2008). Portfolio maintenance can benefit from "technology watching", which is concerned with the monitoring of technological developments and the identification of risks and opportunities (Igartua, 2010, p. 47). Technological opportunities may also be revealed through a comparison of patents between competitors within an industry and a comparison of patents between different industries (Germeraad, 2010, p. 18). Scenario analysis may be used to check over-optimistic or over-pessimistic forecasts. Discovery driven planning may facilitate a technology's development through an evolving implementation plan, which learns and adjusts through the ongoing testing and validation of assumptions (Drew, 2006).

**Project justification and selection.**

***Accounting.***

Accounting methods and tools can be used in financial evaluation, which comprise typically balance sheets, income, cashflow and financial statements (financial accounting), costs of sales and inventories, job-order and process costing (cost accounting), full cost and cost behaviour analysis, strategic budgeting, short-run and long-run analysis (management accounting) (Anthony *et al*., 2004).

***Project economics.***

Project feasibility is determined typically through quantitative evaluation tools, which use discounting and compounding in order to determine economic equivalence in the time-based value of money (Cassimatis, 1988, p. 6). The most common discounting and compounding tools that are used to evaluate potential technological development projects include net present value (NPV), internal rate of return (IRR), annual equivalent amount, capital recovery cost with return, capitalised equivalent, payback period (Cassimatis, 1988, Chapter 4), cost-benefit analysis and life-cycle costs (Samson, 1989, Chapter 2). Technological development portfolios can be evaluated in a collective sense through their return on assets managed (ROAM), return of investment (ROI), return on owner's equity (ROE), return on invested capital (ROIC) (Anthony *et al*., 2004, pp. 412-414) and earnings before interest, tax, depreciation and amortisation (EBIT(DA)) (Anthony *et al*., 2004, p.68). Financial evaluation tools use market prices for a development project's inputs and outputs from the perspective of the project's sponsor (Sell, 1991, pp. 103-104). Technological development projects can be evaluated in a broader socio-economic context through the use of shadow prices, which reflect the true gains and losses to society in a holistic sense (Curry, 1987, pp. 64-65). Furthermore, the value of externalities can be estimated through contingent valuation, travel-cost, hedonic pricing and dose-response (University of Technology Sydney, 2003, p. 106).

**8.5.2 (d) FINANCIAL EVALUATION CONTINUUM.**

Exploitative innovation opportunities can be identified effectively by having a marketing representative in integrated, cross-functional NPD (Jespersen, 2007; Love and Roper, 2009). However, Love and Roper argue that the development of a marketing strategy beyond incremental exploitation should be facilitated through a specialist marketing function, which is separate from exploitative NPD (Love and Roper, 2009, pp. 200-201).

**Concentrated decision locus.**

The candidate contends that strategic exploratory technological portfolio opportunities are facilitated by a concentrated decision locus that consults specialist functions as required, which accords with the observations and arguments that were presented in Chapters 5 and 6 of this dissertation.

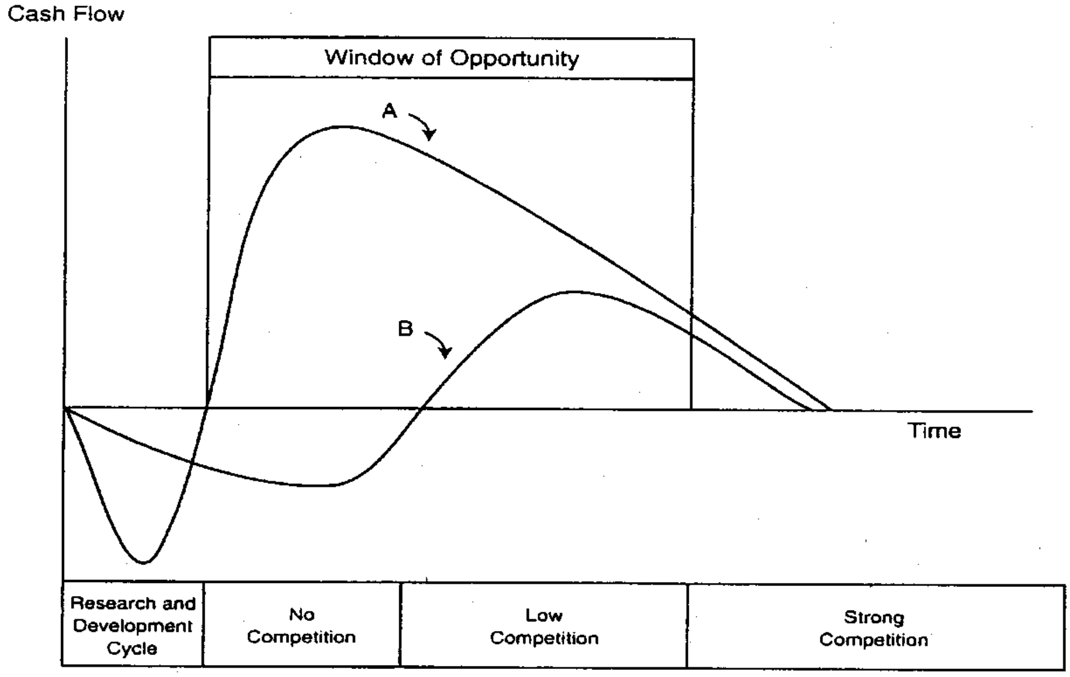
**Opportunity cost.**

The candidate argues that the effective balancing of exploratory and exploitative technological development projects can be made within the context of opportunity cost, which is related to the producer's timing of market entry within a technological paradigm. Levy argues that a window of opportunity exists that provides the maximum return from investment in technological development, which is represented in Figure 19 (Levy, 1998, p. 70). Whilst disruptive technologies carry greater risk and are typified by larger initial negative cash flow, disruptive technologies offer greater potential reward than the relative safety of exploitation through being later to market.

The candidate contends that Levy's window of opportunity in Figure 19 can provide context for the assessment of the opportunity cost for technological development projects because it allows the potential rewards from the exploration of new technological paradigms to be compared directly to the likely outcome from exploitation of existing technological paradigms.

*Figure 19: Cash flow comparison of being first versus later to market.*
***Source:*** *Levy (1998, p. 70).*

*Curve A represents being first to market with a new technological paradigm.*
*Curve B represents exploitation by being later to market through imitation.*




**Ongoing migration from invention to innovation through a balanced portfolio.**

The candidate submits that the explore-exploit continuum for sustainable Financial Evaluation can be represented by an ongoing migration from the **invention** of new technologies to the **innovation** of the new technologies through a balanced technological development portfolio, which allows an enterprise to offset the obsolescence of its existing technological paradigms through disruption or saturation with new technological paradigms. Table 54 summarises the candidate's submission.

***Table 54: Explore-exploit continuum for Financial Evaluation.***
***Source: Candidate's design.***

| **FOCUS** | **INVENTION (exploration)** | **MIGRATION <--->** | **INNOVATION (exploitation)** |
|---|---|---|---|
| **Boardroom strategy** | | | |
| **STRATEGY** | CREATE NEW MARKETS THROUGH COMPETENCY DESTROYING INVENTION. | POSITION ENTERPRISE AS INDUSTRY NUB IN NEW MARKETS. ESTABLISH INSTALLED BASE. | DEVELOP AND PROTECT MARKETS THROUGH COMPETENCY ENHANCING INNOVATION. |

## Shopfloor tactics

| **CULTURAL INVESTMENT** | *"What could be?"* | *"How could there be more?" "What can we lose?"* | *"How can we keep what we have"* |
|---|---|---|---|
| **ENABLING TOOLS** | Concentrated, top-down portfolio creation and decision making with long-term vision.<br><br>Discovery driven planning. Scenario analysis.<br><br>Heterogeneous reference groups.<br><br>Technology watching.<br><br>Patent comparisons.<br><br>Constant portfolio opportunity monitoring through market context and dynamic development tools.<br><br>Bias portfolio to exploration (enterprise re-invention).<br><br>Management and financial accounting. Externality evaluation.<br><br>Project economics based on qualitative reward metrics.<br><br>Opportunity cost analysis based on window of opportunity.<br><br>Switching and imitation behaviour analysis. Competitor imitation disruption mechanisms.<br><br>Offensive marketing to incite imitation behaviour and catalyse diffusion/adoption process. | Integration of marketing specialists and functional consultation and collaboration in portfolio creation and decision making.<br><br>Constant portfolio opportunity and threats monitoring through market context and dynamic development tools.<br><br>Balance portfolio between exploration and exploitation (balance enterprise re-invention with enterprise development).<br><br>Management, financial and cost accounting.<br><br>Project economics based on mix of qualitative reward and quantitative financial metrics.<br><br>Opportunity cost analysis based on window of opportunity.<br><br>Offensive marketing to establish installed base by adding value to low-tier customer relationships. Defensive marketing to protect existing customer relationships. | Dedicated customer/product specific marketing representatives to facilitate innovation and decision making through integrated, cross-functional teamwork and customer channelling. Emphasis on immediate and short-term benefits.<br><br>Homogeneous reference groups. Benchmarking.<br><br>Constant portfolio threats monitoring through market context and dynamic development tools.<br><br>Bias portfolio to exploitation (enterprise development).<br><br>Financial and cost accounting.<br><br>Project economics based on quantitative financial metrics.<br><br>Opportunity cost analysis based on window of opportunity.<br><br>Defensive marketing to prevent top-tier customer relationships from ending or deteriorating.<br><br>Stable and switching consumer analysis. |

### 8.6 ORGANISATIONAL REAGGREGATION.

The candidate has disaggregated nine core processes from a typical manufacturing enterprise and examined them individually in order to develop their unique explore-exploit continuums. Here, the candidate reaggregates the continuums and tests their compatibility as a complete unit against Deming's (1993, pp. 86-89) Systems Analysis Tool, which qualifies the effect of one process on the others. Here, compatibility, synergies and dysfunctionalities can be determined.

The candidate's compatibility analysis of the explore-exploit continuums for core enterprise processes as a complete unit confirmed that the candidate's theory is **synergistic** and devoid of dysfunctionalities. The results from the systems analysis are shown in Figure 20.

| | | QUALITY MANAGEMENT | | | SUPPLY CHAIN | | | PROJECT MANAGEMENT | | | INTELLECTUAL CAPITAL MANAGEMENT | | | RISK MANAGEMENT | | | DESIGN FOR MANUFACTURING AND ASSEMBLY | | | CUSTOMER MANAGEMENT | | | FINANCIAL EVALUATION | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Defect detection. | Defect occurrence reduction. | Defect prevention. | Disintegrated. | Internally integrated. | Internally and externally Integrated. | Organic. | Centralised, top down, functional consultation. | Cross-functional integrated. | Intellectual property and human capital. | Intellectual property and structural capital. | Structural, human and relational capital. | Intuitive. | Quasi-rational. | Rational. | Avoided. | Consulted generalists. | Integrated specialists. | Influence and change behaviour. | Embed new behaviour in mainstream lifestyle. | Customer focus: needs/ satisfaction/ relationships. | Qualitative reward metrics/ bottom-up portfolio. | Combination. | Quantitative financial metrics/ top-down portfolio. |
| **MANUFACTURING** | Craftsmanship. | + | 0 | − | + | 0 | − | + | 0 | − | + | 0 | 0 | + | + | + | + | 0 | − | + | 0 | 0 | + | − | − |
| | Mass production. | + | + | 0 | − | + | − | 0 | + | − | + | + | 0 | 0 | + | + | 0 | + | − | + | + | 0 | 0 | + | 0 |
| | Lean manufacturing. | − | 0 | + | − | + | + | − | − | + | 0 | 0 | + | − | − | + | − | 0 | + | − | 0 | + | − | − | + |
| **QUALITY MANAGEMENT** | Defect detection. | | | | + | 0 | − | + | 0 | − | + | 0 | 0 | + | + | + | + | 0 | − | + | 0 | − | + | 0 | − |
| | Defect occurrence reduction. | | | | 0 | + | 0 | 0 | + | − | + | + | 0 | 0 | + | + | − | + | − | + | + | 0 | 0 | + | 0 |
| | Defect prevention. | | | | − | − | + | − | − | + | + | + | + | − | − | + | − | 0 | + | + | + | + | − | − | + |
| **SUPPLY CHAIN** | Disintegrated. | | | | | | | + | 0 | − | + | + | − | + | + | + | + | 0 | − | + | 0 | 0 | + | − | − |
| | Internally integrated. | | | | | | | 0 | + | 0 | 0 | + | 0 | 0 | + | + | 0 | + | − | + | + | 0 | 0 | + | 0 |
| | Internally and externally Integrated. | | | | | | | − | − | + | 0 | + | + | − | − | + | − | 0 | + | − | 0 | + | − | − | + |
| **PROJECT MANAGEMENT** | Organic. | | | | | | | | | | + | 0 | 0 | + | + | + | + | 0 | − | + | 0 | 0 | + | 0 | − |
| | Centralised, top down, functional consultation. | | | | | | | | | | + | + | 0 | 0 | + | + | − | + | − | + | + | 0 | 0 | + | 0 |
| | Cross-functional integrated. | | | | | | | | | | + | + | + | − | − | + | − | 0 | + | − | 0 | + | − | − | + |
| **INTELLECTUAL CAPITAL MANAGEMENT** | Intellectual property and human capital. | | | | | | | | | | | | | + | + | + | + | 0 | − | + | 0 | 0 | + | − | − |
| | Intellectual property and structural capital. | | | | | | | | | | | | | 0 | + | + | 0 | + | − | + | + | 0 | 0 | + | 0 |
| | Structural, human and relational capital. | | | | | | | | | | | | | − | − | + | − | 0 | + | − | 0 | + | − | − | + |
| **RISK MANAGEMENT** | Intuitive. | | | | | | | | | | | | | | | | + | 0 | − | + | 0 | 0 | + | 0 | − |
| | Quasi-rational. | | | | | | | | | | | | | | | | − | + | − | + | + | 0 | 0 | + | 0 |
| | Rational. | | | | | | | | | | | | | | | | − | 0 | + | − | 0 | + | − | − | + |
| **DESIGN FOR MANUFACTURING AND ASSEMBLY** | Avoided. | | | | | | | | | | | | | | | | | | | + | 0 | 0 | + | − | − |
| | Consulted generalists. | | | | | | | | | | | | | | | | | | | + | + | 0 | 0 | + | 0 |
| | Integrated specialists. | | | | | | | | | | | | | | | | | | | − | 0 | + | − | − | + |
| **CUSTOMER MANAGEMENT** | Influence and change behaviour. | | | | | | | | | | | | | | | | | | | | | | + | 0 | − |
| | Embed new behaviour in mainstream lifestyle. | | | | | | | | | | | | | | | | | | | | | | + | + | 0 |
| | Customer focus: needs/ satisfaction/relationships. | | | | | | | | | | | | | | | | | | | | | | − | 0 | + |

***Figure 20: Compatibility, synergies and dysfunctionalities analysis.***
***Source: Candidate's adaption of*** Deming (1993, pp. 86-89).

**+ Synergistic.** **− Dysfunctional.** **0 Compatible, but not synergistic.**

## 8.7 AMBIDEXTERITY MODEL OF INNOVATION MANAGEMENT.

The candidate applies the evaluation from the Systems Analysis Tool in the previous section towards the development of their ambidexterity model in this section. The section is organised in four parts. Firstly, a hypothesis is submitted that represents an enterprise-wide explore-exploit continuum. Secondly, the candidate develops a model for the management of multiple innovations within an enterprise. Thirdly, the candidate develops a model for how change can be managed within an enterprise. Fourthly, the candidate's ambidexterity model is presented.

### 8.7.1 Hypothesis 3: Generic migration path (H3).

The candidate submits that the optimal benefit that can be derived from a technological paradigm throughout the life of the technological paradigm is achieved according to the generic migration path defined in Hypothesis 3 (**H3**). The generic migration path in **H3** prescribes the optimal boardroom strategies and shopfloor tactics that allow an enterprise to secure first-mover advantages through a disruptive technological paradigm and then affect the paradigm's exploitation through an ordered migration to a lean state.

**(H3):** The organisation of processes within a manufacturing enterprise for the manufacture of a technological paradigm follow a generic migration path, which is defined by the aggregation of the explore-exploit continuums in Chapter 8 of this dissertation.

### 8.7.2 Enterprise configuration.

A question that requires resolution in order to develop an ambidexterity model based on **H3** is how can multiple innovations be managed within an enterprise? The candidate submits in this section a model for enterprise configuration.

#### 8.7.2 (a) ENTERPRISE ARCHITECTURE CONTINUUM.

The candidate asserts that the continuum for enterprise architecture is consistent with the continuum for manufacturing, which was summarised in Table 42 of this dissertation.

#### 8.7.2 (b) MULTIPLE INNOVATION DOMAINS.

The candidate's assertion for the continuum of enterprise configuration represents the normal development of a discrete technological paradigm. An issue that requires resolution is how an enterprise can configure in order to manage exploration and exploitation in multiple innovation domains. Innovation in multiple innovation domains can arise from competition at sub-paradigm levels within technological paradigms or from competition across multiple technological paradigms. An outcome from competition in multiple innovation domains is the challenge to manage multiple technological trajectories with unique degrees and rates of technological development.

The candidate contends that the effective management of multiple innovation domains is expedited through two strategic steps. Firstly, **technological trajectories should be segregated** from each other. Secondly, **each technological trajectory should be allowed to evolve without interference** according to normal technological development that accords with the hypotheses the candidate submitted in Chapter 6 of this dissertation.

**Activity segregation.**

Several authors advocate the segregation of exploratory activity from exploitative activity (*e.g.* Hayes and Wheelwright, 1979, p. 139; Dougherty and Hardy, 1996, p. 1145; Benner and Tushman, 2003, p. 252; Magnusson *et al*., 2009, p. 4). According to Raisch and Birkinshaw, activities that are separated structurally may maintain a high degree of strategic purity (Raisch and Birkinshaw, 2008, p. 399). Whilst ambidexterity may be facilitated through coupled loosely quasi-configurations (van Looy *et al*., 2005, p. 208), the candidate has argued for a punctuated equilibrium model of ambidexterity (that encompasses the duality approach to ambidexterity) rather than the sole adoption of a duality approach to ambidexterity. The candidate argues that a duality approach to ambidexterity can interfere with the natural evolution of the three dominant manufacturing paradigms, which according to the candidate's hypotheses represents optimal efficiency. The candidate argues that an outcome from the duality approach to ambidexterity is the development and adoption of hybrid manufacturing paradigms, which may compromise the evolution of the three dominant manufacturing paradigms.

**Hybrid manufacturing paradigms.**

The candidate argues that hybrid manufacturing paradigms[140] are an attempt to manage the complexity of multiple innovation domains through a one-size-fits-all approach, which is based on a combination of the competitive strengths that derive from the three dominant manufacturing paradigms.

**8.7.2 (c) ENTERPRISES WITHIN AN ENTERPRISE.**

The candidate's contention of activity segregation creates effectively enterprises within enterprises. An issue that requires resolution is how the proactivity dilemma can be managed, which the candidate argues centres upon human resource management.

**Human Resource Management (HRM).**

Several authors argue that the simultaneous pursuit of exploration and exploitation requires an enterprise to have a diverse pool of leadership styles and innovation capabilities available

[140] Examples of hybrid paradigms include agile manufacturing (*e.g.* Montgomery and Levine, 1996; Richards, 1996) and leagile manufacturing, which is regarded to be hybrid of lean and agile manufacturing (*e.g.* Mason-Jones *et al*., 2000).

throughout the enterprise (*e.g.* Hayes and Wheelwright, 1979, p. 139; Dombrowski *et al*., 2007, p. 200; Bel, 2010, p. 59; Igartua, 2010, p. 43).

***Exploitative HRM.***

The candidate has argued that it pays an exploitative enterprise to invest in and retain employees who have a propensity for customer oriented behaviour. According to Homburg, employees with a propensity for empathising with customers are more able to have accurate perceptions of their customer's needs, which can be further enhanced with training. Furthermore, empathic ability can lead to increased customer satisfaction levels, which compound through the development of relational history (Homburg *et al*., 2009b, pp. 76-78). Liker and Hoseus explain that Toyota embraces the concept of human value streams, which mirrors the concept of manufacturing value streams. The banishment of waste from human value streams entails the development and retention of employees who embrace *kaizen*, are passionate about personal development and Toyota culture and above all are committed to do the best for the customer (Liker and Hoseus, 2008, Chapter 2). The candidate argues that enterprises with exploitative capability should attempt to retain their exploitative capability for three reasons. Firstly, the adaptation of competency-destroying activities in an enterprise that is configured for competency-enhancement is disruptive highly to the enterprise (Gatignon *et al*., 2002, p. 1105). Secondly, the enterprise can leverage the human resources that are embedded in its human value streams for future exploitation. Thirdly, the enterprise can balance exploitation with exploratory technological development projects, which can be segregated from exploitation. Exploratory technologies may evolve into future exploitation opportunities, which can offset the obsolescence from the disruption or saturation of aging technological paradigms and continue to engage employees with an exploitative propensity.

***Exploratory HRM.***

The candidate argues that the introduction of exploratory activity into an exploitative enterprise may allow the transfer of employees to more productive roles. Whilst an exploitative enterprise may have effective exploitative operations and an exploitative culture, there may be employees who are accomplished at exploitation but have a greater propensity towards exploration. Potential candidates for transfer may include employees who can become passionate sponsors of exploration (McDermott, 1999, pp. 638-639), greet change with excitement and happiness (Vakola *et al*., 2004, p. 90) and are talented social isolates who could be provided with an environment where they may express their unique knowledge without social bias (Thomas-Hunt *et al*., 2003, pp. 474). The candidate has argued throughout this dissertation that exploration is characterised by groupwork rather than teamwork. Potential candidates may also include employees who are resistive to teamwork. Several authors have argued that the formation of dedicated teams and a requirement for teamwork may provoke resistance to change in some individuals. Shapiro and Kirkman found that the imposition of teamwork can create a perception of anticipatory injustice, which was characterised by an expectation of unfair outcomes (Shapiro and Kirkman, 1999, p. 64). Employees may also regard the imposition of teamwork as a violation of fairness and have concerns about increased work-load, uncertain role definition and the availability of management and social support (Kirkman *et al*., 2000, p. 74). Paul *et al*. contend that teamwork may end in disillusionment that can arise from breaches in psychological contracts, which violated an individual's belief of their entitlements (Paul *et al*., 2000, pp. 482-483). The candidate suggests finally that an exploitative enterprise may employ management tactics in the case where suitable employees for transfer to exploration can not be located for management positions. Siggelkow and Rivkin argue that exploration at a middle management level can be stimulated by the creation of incentives for the consideration of an enterprise's strategic imperatives ahead of parochial interests. Exploratory incentives may be created by the provision of an unlimited exploratory licence in prescribed exploration domains and the installation of a requirement for the regular and mandatory submission of exploratory ideas for executive consideration. Moreover, Siggelkow and Rivkin contend that executives who provide immutable resistance to exploration may require removal (Siggelkow and Rivkin, 2006, pp. 792-793).

**8.7.2 (d) HETEROGENEOUS ACTIVITIES.**

The candidate contends that the segregation of innovation domains within an enterprise implies that at any given point in time the enterprise can have activities dedicated to exploration, exploitation and the transition from exploration to exploitation according to the normal development of a technological paradigm.

The candidate submits that the heterogeneity of activities resulting from the segregation of innovation domains provides numerous strategic and competitive advantages. The candidate argues paradoxically that the segregation of activities and the avoidance of contrived ambidexterity through a duality approach will result in fostering innovation capabilities. A dynamic environment exists, which comprises the hallmarks of an ambidextrous state.

**Dynamic innovation capabilities.**

The candidate argues that the establishment of segregated exploratory enterprises within an exploitative incumbent enterprise can foster dynamic innovation capabilities throughout the collective enterprise. An internal exploratory enterprise with self-autonomy can form its own identity and in doing so set its own management agenda, which bypasses the tension from integration into an exploitative architecture and conformance to exploitative objectives, timetables and performance metrics (McDermott, 1999, p. 641). Furthermore, the exploratory enterprise can structure its own networks in a manner that is conducive to exploration (Cesaroni *et al*., 2005, pp. 230-231). Stock *et al*. suggest that a self-autonomous exploratory enterprise can provide the exploitative incumbent enterprise with the capability to “act small”, which is akin to a start-up enterprise (Stock *et al*., 2002, p. 546). The candidate argues that the exploitative incumbent may derive further benefits from the concentration of explorative activities into separate entities. Saemundsson suggests that the concentration of exploratory research and development costs into a single cost centre allows more effective management of the costs (Saemundsson, 2005). Richtner and Rognes argue that the concentration of exploratory activity allows greater flexibility in exploratory project management, which has the advantages of more effective communication and problem solving (Richtner and Rognes, 2008, pp. 136-137). Finally, the candidate argues that the collective enterprise can benefit from the self-reliance of its segregated exploratory enterprises because self-reliance fosters the development of technological and exploratory capabilities, which are contained within the collective enterprise and can overspill throughout the collective enterprise. The exploratory enterprises’ self-reliance can be developed by internal supply, which does not outsource outside of the collective enterprise based on exploitative make-versus-buy analysis. Self-reliance can have the positive benefits of protecting intellectual capital and developing the overall exploratory capability of the collective enterprise for four key reasons. Firstly, internal sourcing by the exploratory enterprise within the collective enterprise may be based on exploratory performance criteria and not the exploitative criteria that are used typically for external supply sourcing, which can demand an increase in the exploratory capabilities of the collective enterprise (Feldmann and Olhager, 2008). Secondly, the development of internal explorative capability can enhance the competency to leverage external exploitative capabilities (Hoang and Rothaermel, 2010, p. 754). Thirdly, the development of internal exploratory capability through self-reliance promotes investment in research and development because external substitutes are avoided (Cuervo-Cazurra and Un, 2010, p. 773). Fourthly, the exploratory enterprises can act as internal technological intermediaries that facilitate open innovation throughout the collective enterprise, which has the effect building overall absorptive capacity (Spithoven *et al*., 2010, p. 139).

**Dynamic cultural environment.**

The candidate argues that the segregation of technological trajectories within an enterprise can promote a dynamic cultural environment that may stimulate overall creativity and employee motivation. The heterogeneity of activities that can arise allows the enterprise the simultaneous and total concentration of the full spectrum of its exploratory, exploitative and transitional exploration to exploitation capabilities, which bypasses the need to develop a mono-culture throughout the enterprise. The diversity that heterogeneity creates may act as a wellspring of creativity and provide greater opportunities for employee self-development and career path options.

### 8.7.3 Change management.

A question that requires resolution in order to develop an ambidexterity model based on **H3** is how can the change that is implied in **H3** be managed by the enterprise? The candidate submits in this section a model for change management.

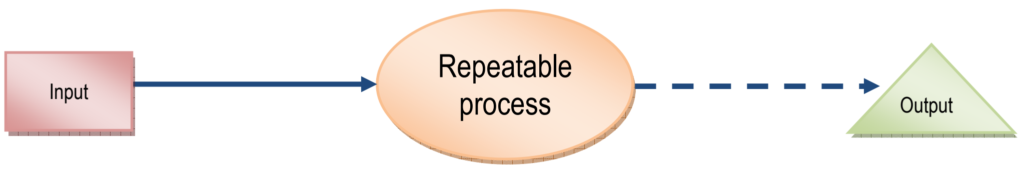
The candidate contends that the causal nature of LM and the organic indeterminacy of CR avail themselves to contrasting approaches of change management.

The candidate's contention was formed after an interview of Dyan Loveday where the candidate explored post-structuralist approaches to the design of manufacturing systems (Loveday, 2008).

**Scientific systems modelling.**

The design and modelling of systems in contemporary manufacturing enterprises centres typically on the structuralist approach of using scientific models that are translated into the management of human behaviour. The structuralist approach is founded on the principle of cause and effect, which argues that organisational activity can be perceived as the transformation of inputs into outputs via a process. The logic behind the structuralist approach is that for any given input stimulus there are a series of unfolding mechanistically ordered events, which provide a pre-determinable output. Enterprises that afford truth status to scientific modelling place emphasis on the repeatability of processes and employ quantifiable metrics in order to gauge the reliability of outputs. The structuralist approach of scientific modelling applies science to the management of social change.

*Figure 21: Scientific systems modelling.*
*Source: Candidate's design.*

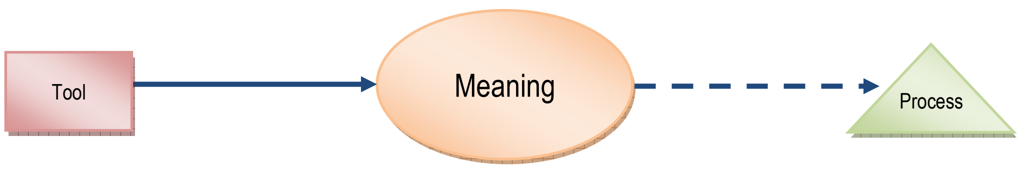



**Relational systems modelling.**

The post-structuralist relational approach to systems modelling differs fundamentally to the scientific approach because it first incites behaviour, which is then translated into science. Relational systems modelling argues that the interaction between an individual and their environment results in the emergence of production tools, which become a medium for social interaction. Emerged production tools provide a focal point for the exchange of ideas and meaning making, which stimulates the improvement and adaption of the production tools to suit the local conditions. The meaning that is instilled in a production tool represents the common history, understanding, culture and language[141] that defines the production tool and its use. A fundamental outcome from the instilment of meaning in production tools is a specific organisation of activities for the tool's use that can be mapped in terms of repeatable operations. Furthermore, the tools are optimised for the local conditions and the operations for their use are understood and accepted universally as valid. The relational approach asserts that human behaviour translates into a scientifically measureable process. The essence of relational systems modelling is the avoidance of prescription, whereby activity is directed **in relation to** organisational objectives, which are described in broad terms. The avoidance of prescribed activity and the generalisation of objectives is based on three assumptions. Firstly, non-prescription and generalisation are conducive to the agreement of the enterprise's objectives and key outcomes, which fosters unification of purpose. Secondly, non-prescription and generalisation accommodate variation in individual interpretation, which is a prime issue in the standardised approach of scientific management. Thirdly, activities will evolve in effectiveness provided that the activities are interpreted in relation to the achievement of the enterprise's objectives.

The candidate asserts that a relational approach to management allows individuals with differing perceptions to grow meaning into their activities within a unifying framework in an exploratory context. The instilment of meaning into an enterprise's activities allows scientific modelling, which can then be exploited as repeatable processes. Table 55 summarises the dominant narratives of the scientific and relational approaches to systems modelling.

***Figure 22: Relational systems modelling.***
***Source: Candidate's design.***




141 Relational systems modelling can explain why host systems are difficult to replicate in non-originating contexts. *E.g.* Toyota's efforts to establish overseas transplant enterprises.

*Table 55: Dominant narratives of the scientific and relational approaches to systems modelling.*
*Source: Candidate's design based on* Loveday (2008).

| RELATIONAL APPROACH (Post-Structuralist) | SCIENTIFIC APPROACH (Structuralist) |
|---|---|
| Pre-dominant design exploration. *"Behaviour translates into science".* | Post-dominant design exploitation. *"Science translates into behaviour".* |
| Objective. | Input. |
| Key outcome. | Output. |
| Supporting strategy and activities. | Process. |
| Indicators. | Performance metrics. |

### 8.7.4 Solution to the productivity, innovator's and proactivity dilemmas.

The candidate submits that a solution to the productivity, innovator's and proactivity dilemma may be achieved by the organisation of processes according to the generic migration path defined by **H3** under the conditions defined in Section 8.7.2 Enterprise configuration and Section 8.7.3 Change management in this dissertation.

## 8.8 SUMMARY.

The findings from the testing of hypotheses in Chapter 6 of this dissertation were transposed to processes other than manufacturing. Nine core processes for a typical manufacturing enterprise were addressed by the candidate, which were categorised under operations management, product development and strategic planning. The findings from Chapter 6 were transposed to each process individually, in order to establish the unique explore-exploit continuum for each process. A question that required resolution in order to guide the research was what are the enterprise's strategic imperatives according to the hypotheses in Chapter 6 of this dissertation? The candidate defined the enterprise's strategic imperatives through the application of Francis and Bessant's (2005) Model of Innovation Targeting. The candidate then researched the nine individual processes within the context of the enterprise's strategic imperatives according to three criteria. Firstly, the theory for the process's function. Secondly, the core methods and tools for the execution of the process. Thirdly, how the process can be managed strategically through an explore-exploit continuum. The candidate established comprehensively an explore-exploit continuum for each process from "**boardroom strategy**" to "**shopfloor tactics**". Then, the candidate aggregated the individual explore-exploit continuums into a complete unit and tested their compatibility against Deming's (1993, pp. 86-89) Systems Analysis Tool. The results showed that when the individual explore-exploit continuums are aggregated into a complete unit they are **synergistic** and devoid of dysfunctionalities.

The candidate applied the findings from the systems analysis towards the development of their ambidexterity model. The candidate formed a third hypothesis (**H3**) for the optimal benefit that can be derived from a technological paradigm throughout its lifecycle. **H3** asserted that the aggregation of the individual explore-exploit continuums into a complete unit represents the optimal boardroom strategies and shopfloor tactics that allow an enterprise to generate a transformational innovation and then affect the innovation's exploitation through an ordered migration to a lean state. The candidate believed that **H3** formed the foundation of a potential ambidexterity model. Here, two questions arose that required resolution in order to develop fully an ambidexterity model. Firstly, how can multiple innovations be managed within an enterprise? Secondly, how can the change that is implied in **H3** be managed by the enterprise? The candidate answered the first question by developing a model for enterprise configuration, which addressed the issues of the enterprise's architecture and human resource management. The candidate answered the second question by developing a model of change management.

The candidate submits that their transposition of the findings from the testing of hypotheses in Chapter 6 of this dissertation achieved substantially the outcome that was planned in the strategic argument mapped in Table 3 of this dissertation. There are three key parts to the outcome of this chapter, which can be summarised as follows. Firstly, the candidate submitted an ambidexterity model, which comprised **H3** and the candidate's models for enterprise configuration and change management. Secondly, the candidate's contention of a proactivity dilemma was consistent with the ambidexterity model. Thirdly, the candidate improved significantly the theory for ambidexterity.

# CHAPTER 9
# CONCLUSION

## 9.1 INTRODUCTION.

This chapter summarises and concludes the candidate's dissertation. The achievement of objectives, original contribution and potential future research directions are reported.

## 9.2 RESEARCH SUMMARY.

This dissertation presented a fresh perspective on Toyota's system of "lean manufacturing" in order to address a key issue in the literature for innovation and operations management and in doing so contributed significantly to the theory of ambidexterity. The contemporary literature for innovation management and manufacturing systems abounds with calls for research into the issue of contextual operations design, which moves beyond a one-size-fits-all approach to innovation and manufacturing. Contextual operations design centres upon the theory for ambidexterity, which addresses the management of **exploration** for the future with **exploitation** of the *status quo*. Exploration and exploitation are antagonistic approaches to innovation where exploration is characterised by technology-push and exploitation by customer-pull. Technology-push changes consumer behaviour and installs new needs through disruptive innovation. Customer-pull reacts to existing consumer needs and satisfies them through continuous incremental improvement. Ambidexterity is important for two reasons. Firstly, the structures and capabilities for exploration and exploitation are different fundamentally. Secondly, the exploitation of aging technologies tends to diminishing returns and is threatened with obsolescence. The theory for ambidexterity strives for the resolution of productivity and innovator's dilemmas, which act to reinforce each other. The productivity dilemma asserts that the routinisation required for efficient exploitation is incompatible with the flexibility required for exploration. The innovator's dilemma asserts that the continuous incremental improvement of exploitation inhibits exploratory innovation. Whilst ambidexterity is an important theme in the contemporary literature for innovation management and manufacturing systems, the candidate observed that the theory for a unifying framework for ambidexterity is not reported. Moreover, the theory for the methods and tools that are used for the execution of ambidexterity require significant development. The candidate further observed a singular event at Toyota when in 2007 Toyota announced it will focus on disruptive innovation (called *kakushin*) in an environment of continuous incremental improvement (called *kaizen*). Here, the candidate argued three key points. Firstly, the candidate argued that Toyota's position epitomises the open issues in the theory for ambidexterity. The candidate contended that Toyota's system of "lean manufacturing" is an exemplar of exploitation because Toyota's business model is customer-pull: manufacture only when required and manufacture only products the customer requires. Furthermore, the growth and success of Toyota is founded upon excellence in *kaizen* and amongst industry observers, *kakushin* is regarded to be disparate to *kaizen*. The second point the candidate argued was that a new perspective could be presented on lean manufacturing through an interdisciplinary approach of innovation, economic and behavioural criteria and in doing so insight could be gained into the open ambidexterity issues. Thirdly, the candidate argued that a third dilemma will emerge in the research, which the candidate has named the proactivity dilemma. The proactivity dilemma works in concert with the productivity and innovator's dilemmas and contends that exploratory behaviour is perceived increasingly non-proactive as proactivity in exploitation increases. Here, two questions required resolution: how can *kakushin* be reconciled with *kaizen* and how can the outcome be applied towards the advancement of ambidexterity theory? The candidate formed three objectives for this dissertation that were based on the candidate's argument and the two questions that required resolution. Objective 1 was to evaluate lean manufacturing through innovation, behavioural and economic criteria. Objective 2 was to apply the insight gained from Objective 1 to the theory for ambidexterity. Objective 3 was to provide theory for the existence of a proactivity dilemma. The candidate mapped a **strategic argument** in order to steer the research, which was outlined in Table 3 of this dissertation.

The candidate instituted a comprehensive literature survey in Chapter 2 of this dissertation, which resulted in three outcomes. Firstly, the candidate showed that *kakushin* is new in the literature and that whilst *kakushin* has come to the attention of ambidexterity scholars, its reconciliation within the theory for lean manufacturing is in its infancy. Secondly, the candidate identified profound theory that can be used to present a new perspective on lean manufacturing, through innovation, behavioural and economic criteria. Thirdly, the fundamental outcome from Chapter 2 for the strategic argument in Table 3 of this dissertation was that the candidate showed that the research rationale and objectives of this dissertation are justified.

The candidate outlined their approach to how lean manufacturing will be evaluated in Chapter 3 of this dissertation, which formed a foundational part of the strategic argument that is mapped in Table 3 of this dissertation. The candidate presented a new perspective on lean manufacturing that was founded in the theory the candidate identified in the literature survey of this dissertation. The candidate formed a relationship between lean manufacturing and its predecessors, which comprised mass production and craftsmanship manufacturing. The relationship the candidate formed was characterised by **three dominant manufacturing paradigms**, which the candidate argued are equal to each other and are implied in a **classical technological evolution**. Here, lean manufacturing is considered within the context of the progress of the automobile as a technological **paradigm** along a technological **trajectory**. The significance to this dissertation is that craftsmanship manufacturing dominated during the automobile's disruptive origin whilst mass production dominated during the transition to lean manufacturing, which represents a continuum of manufacturing from exploration to exploitation.

The candidate detailed established theory and developed their new perspective on lean manufacturing in Chapter 4 of this dissertation. The candidate showed that the relationship between lean manufacturing and its predecessors can be evaluated through six dimensions of innovation, which encompass the established theory for lean manufacturing, innovation management, behavioural science and economics. The six dimensions of innovation are: (1) Object of change, (2) Degree and frequency of change, (3) Relative time to market, (4) Technological trajectories, (5) Cost dynamics and (6) Relationship to the dominant design. The candidate concluded that their development of a new perspective on lean manufacturing in Chapter 4 achieved substantially the outcome that was planned in the strategic argument mapped in Table 3 of this dissertation. There were two key parts to the outcome, which can be summarised as follows. Firstly, the theory contained three dominant manufacturing paradigms that evolved in a systematic manner in which lean manufacturing is equal to the other two paradigms. Secondly, lean manufacturing was confirmed to be the exploitative extreme of an explore-exploit continuum for manufacturing.

The practices of lean manufacturing were inserted into the theory that was developed in Chapter 4 of this dissertation and were evaluated against the theory in Chapter 5 of this dissertation. The candidate concluded that their evaluation of lean manufacturing in Chapter 5 achieved substantially the outcome that was planned in the strategic argument mapped in Table 3 of this dissertation. There were four key parts to the outcome, which can be summarised as follows. Firstly, the precipitative events in the automobile's technological trajectory were confirmed. Here, the automobile's technological trajectory is consistent with a classical technological evolution. Secondly, three dominant manufacturing paradigms were confirmed and their eras were established, which are consistent with theory established in Chapter 4 of this dissertation for craftsmanship, mass production and lean manufacturing. Thirdly, the key attributes of craftsmanship, mass production and lean manufacturing were determined and their competitive advantages were established. Fourthly, the manner in which the key attributes and competitive advantages for craftsmanship, mass production and lean manufacturing evolved was established.

The candidate formed and tested hypotheses in Chapter 6 of this dissertation for the relationship between the three dominant manufacturing paradigms of craftsmanship, mass production and lean manufacturing. The formation and testing of the candidate's hypotheses was a key part of the strategic argument that is mapped in Table 3 of this dissertation. The formation of the hypotheses was based on the evaluation of lean manufacturing in Chapter 5 against the theory in Chapter 4 of this dissertation. Two primary hypotheses and three sub-hypotheses were formed by the candidate. The first primary hypothesis (**H1**) asserted that the three dominant manufacturing paradigms evolve in a systematic manner in which lean manufacturing is equal to the other two paradigms. The second primary hypothesis (**H2**) asserted that the three dominant manufacturing paradigms evolve around a dynamic waste threshold. **H2** was developed through three sub-hypotheses (**H2a**, **H2b** and **H2c**). **H2a** asserts that the dynamic waste threshold is a function of the dominant design's efficiency. **H2b** asserts that each dominant manufacturing paradigm has a unique waste profile around which its architecture is organised. **H2c** asserts that the net outcome from a dominant manufacturing paradigm's architecture is the facilitation of the dominant innovation object and mechanism that is appropriate for the contextual conditions the paradigm operates under. The candidate tested the hypotheses against existing strategic, innovation and economic models, which constituted three tests. **Test 1** evaluated the ability of a dominant manufacturing paradigm to preserve a competitive advantage over the other paradigms against Porter's (1996) Model of Strategy. **Test 2** evaluated the return on investment the three dominant manufacturing paradigms generated from the adoption of a generic manufacturing system innovation against Paap and Katz's (2004) Model of Dynamic Innovation. **Test 3** evaluated the capability of the three dominant manufacturing paradigms to create value against Hines *et al*'s (2004) Model of Value Creation. The candidate concluded that their formation, testing and evaluation of hypotheses in Chapter 6 achieved the outcome that was planned in the strategic argument mapped in Table 3 of this dissertation. There were four key parts to the outcome, which can be summarised as follows. Firstly, there is a clear and **systematic order** in which the three dominant manufacturing paradigms evolve and the way they exploit competitive advantages. Secondly, lean manufacturing is **equally superior** to the other two dominant manufacturing paradigms. Thirdly, the contextual conditions under which Toyota's innovation mechanisms are facilitated reflect the three dominant manufacturing paradigms and are summarised: *kakushin* (craftsmanship), *kaikaku* (mass production) and *kaizen* (lean manufacturing). Fourthly, the candidate concluded that the hypotheses are supported by the test results.

Chapter 7 of this dissertation developed the theory for the transposition of the findings from the testing of hypotheses in Chapter 6 of this dissertation to processes other than manufacturing (quality management, supply chain management, product development *etc*.). The state-of-the-art in the theory for the productivity dilemma, innovator's dilemma and ambidexterity was established. The theory for the candidate's concept of a proactivity dilemma was developed. The candidate concluded that their formation of the theory in Chapter 7 achieved substantially the outcome that was planned in the strategic argument mapped in Table 3 of this dissertation. There were three key parts to the outcome, which can be summarised as follows. Firstly, the findings from the testing of hypotheses in Chapter 6 of this dissertation can be transposed from manufacturing to processes other than manufacturing through an **explore-explore continuum**. Secondly, the theory for the proactivity dilemma works in concert with the productivity and innovator's dilemmas. Thirdly, the framework for the candidate's ambidexterity model was defined.

The findings from the testing of hypotheses in Chapter 6 of this dissertation were transposed to processes other than manufacturing in Chapter 8 of this dissertation. Nine core processes for a typical manufacturing enterprise were addressed by the candidate, which were categorised under operations management, product development and strategic planning. The findings from Chapter 6 were transposed to each process individually, in order to establish the unique explore-exploit continuum for each process. A question that required resolution in order to guide the research was what are the enterprise's strategic imperatives according to the hypotheses in Chapter 6 of this dissertation? The candidate defined the enterprise's strategic imperatives through the application of Francis and Bessant's (2005) Model of Innovation Targeting. The candidate then researched the nine individual processes within the context of the enterprise's strategic imperatives according to three criteria. Firstly, the theory for the process's function. Secondly, the core methods and tools for the execution of the process. Thirdly, how the process can be managed strategically through an explore-exploit continuum. The candidate established a comprehensive explore-exploit continuum for each process from "**boardroom strategy**" to "**shopfloor tactics**". Then, the candidate aggregated the individual explore-exploit continuums into a complete unit and tested their compatibility against Deming's (1993) Systems Analysis Tool. The results showed that when the individual explore-exploit continuums are aggregated into a complete unit they are **synergistic** and devoid of dysfunctionalities. The candidate then applied the findings from the systems analysis towards the development of their ambidexterity model. The candidate formed a third hypothesis (**H3**) for the optimal benefit that can be derived from a technological paradigm throughout its lifecycle. **H3** asserted that the aggregation of the individual explore-exploit continuums into a complete unit represents the optimal boardroom strategies and shopfloor tactics that allow an enterprise to generate a transformational innovation and then affect the innovation's exploitation through an ordered migration to a lean state. The candidate believed that **H3** formed the foundation of a potential ambidexterity model. Here, two questions arose that required resolution in order to develop fully an ambidexterity model. Firstly, how can multiple innovations be managed within an enterprise? Secondly, how can the change that is implied in **H3** be managed by the enterprise? The candidate answered the first question by developing a model for enterprise configuration, which addressed the issues of the enterprise's architecture and human resource management. The candidate answered the second question by developing a model of change management. The candidate concluded that their transposition of the findings from the testing of hypotheses in Chapter 6 of this dissertation achieved substantially the outcome that was planned in the strategic argument mapped in Table 3 of this dissertation. There are three key parts to the outcome of Chapter 8, which can be summarised as follows. Firstly, the candidate submitted an **ambidexterity model**, which comprised **H3** and the candidate's models for enterprise configuration and change management. Secondly, the candidate's contention of a proactivity dilemma was consistent with the ambidexterity model. Thirdly, the candidate improved significantly the theory for ambidexterity.

## 9.3 ACHIEVEMENTS AGAINST RESEARCH OBJECTIVES.

The candidate's achievements against the research objectives are summarised in Table 56.

*Table 56: Achievements against research objectives.*

| | OBJECTIVE | RESULTS | COMMENTS |
|---|---|---|---|
| **1** | Evaluate Lean Manufacturing through innovation, behavioural and economic criteria. | Achieved. | The candidate has submitted and tested explicitly hypotheses **H1** and **H2** and tested implicitly sub-hypotheses **2a**, **2b** and **2c**. |
| **2** | Apply the insight gained from Objective 1 to the theory for ambidexterity. | Significant contribution. | The candidate has submitted an ambidexterity model of innovation management based on hypothesis **H3**. |
| **3** | Provide theory for the existence of a Proactivity Dilemma. | Advanced substantially. | The candidate asserts that their theory for an Insidious Plant within a Proactivity Dilemma complements the Productivity and Innovator's Dilemmas. |

## 9.4 ORIGINAL CONTRIBUTION.

The candidate submits this dissertation as an original work, contributing significantly to the theory of Lean Manufacturing, which centred upon exploration in an exploitative environment. The contribution from this dissertation spans multiple disciplines and provides an improvement in coherency. This dissertation contributed in two ways that were originated by the candidate and described next.

Firstly, the candidate combines existing concepts and theory into a cross-disciplinary framework. Then the evaluation of Lean Manufacturing within this framework that gives a new perspective on Lean Manufacturing itself. Here, the candidate showed that Lean Manufacturing can be explained from ordered antecedents, which follow a classical technological evolution.

Secondly, as an outcome from the candidate's new perspective on Lean Manufacturing, this dissertation specifies the theory for a universal model of ambidexterity, which resolves fundamentally the Productivity and Innovator's Dilemmas. Here, the candidate showed that *kakushin*, *kaikaku* and *kaizen* can be represented by an exploration-exploitation continuum, which reconciles the competing models of ambidexterity according to contextual conditions. The candidate then conceived, developed and tested the theory for his novel concepts of a "Dynamic Waste Threshold", "Insidious Plant" and "Proactivity Dilemma", which work in concert with the Productivity and Innovator's Dilemmas and help substantially to explain the mechanism behind their operation. Moreover, the methods and tools used for nine core processes of a typical manufacturing enterprise, categorised by Operations Management, Product Development and Strategic Planning were prescribed from "boardroom" strategy to "shopfloor" tactics to manage ambidexterity. A summary of the key contributions originated by the candidate in this dissertation is specified in Table 57.

***Table 57: Summary of the candidate's key original contributions in this dissertation (by discipline).***

| DISCIPLINE | CANDIDATE'S KEY ORIGINAL CONTRIBUTIONS |
|---|---|
| **Operations Management.** | • Detailed de-construction of Lean Manufacturing that shows its evolution from ordered antecedents (Craftsmanship and Mass Production).<br>• Detailed analysis and reconciliation of Toyota's innovation mechanisms (*kakushin*, *kaikaku* and *kaizen*) that explains their processes and appropriate contextual conditions.<br>• Conceiving, development and testing of a "Dynamic Waste Threshold" and the specification of its theory.<br>• Conceiving, development and testing of an "Insidious Plant" and the specification of its theory.<br>• Detailed prescription of the methods and tools for the synergistic management of exploration and exploration across nine core organisational processes of a typical manufacturing enterprise - from "boardroom strategy"' to "shopfloor" tactics. |
| **Innovation Management.** | • Specification of the theory for a universal model of ambidexterity that reconciles competing models of ambidexterity and resolves fundamentally the Productivity and Innovator's Dilemmas.<br>• Conceiving and development of a "Proactivity Dilemma" that works in concert with the Productivity and Innovator's Dilemmas.<br>• Significant contribution to the theory of technological paradigms, technological trajectories, dominant designs and hierarchical innovation.<br>• Improved coherency between the discipline of Innovation Management and other disciplines (Operations Management, Economics, Behavioural Science *etc.*). |
| **Economics.** | • Application of opportunity cost and utility theory to the theory of value creation in Lean Manufacturing. |
| **Behavioural Science.** | • Conceiving and development of a "Proactivity Dilemma" and the specification of its groundwork theory. |

## 9.5 FUTURE RESEARCH.

The candidate regards this dissertation as a foundation for an ambidexterity model of innovation management that addresses the productivity and innovator's dilemmas, which although comprehensive in scope has limitations and weaknesses that could be addressed by future research. The candidate concentrated in this dissertation on the development of ambidexterity theory, which could be tested and developed further through empirical testing. The candidate suggests that two key areas could be tested over long-term studies. Firstly, the empirical testing of **H1** and **H2** in enterprises that have organised around and evolved with discrete technological paradigms. *E.g.* the quantification of dominant design efficiency and associated waste profiles. Secondly, the simultaneous testing of the proactivity dilemma based on appropriate psychometrics.

The candidate believes that the theory within this dissertation could also be developed further. A key area for theoretical development is the management of the candidate's ambidexterity model for innovation management. The candidate has argued for the segregation of technological trajectories within an enterprise that is overseen by an overarching meta-model of ambidexterity. Here, the candidate suggests that two issues require theoretical development. Firstly, the issue of how the segregation of technological trajectories can be managed effectively. Secondly, how the meta-model of ambidexterity could be administered in an enterprise, in light of the proactivity dilemma.

## 9.6 SUMMARY.

This chapter summarised and concluded the candidate's research in this dissertation. The achievement of objectives, original contribution and potential future research directions were summarised. As a consequence, the candidate hopes sincerely that the objectives outlined in Chapter 1 of this dissertation have been met substantially.

# CHAPTER 10
# REFERENCES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# APPENDIX A
# LEAN MANUFACTURING: POTENTIAL PROBLEMS

## A 1.1 INTRODUCTION.

The candidate presents in this section potential problems that may be encountered by enterprises that attempt the implementation of LM. The problems presented here are the candidate's contentions and were formulated during the course of this dissertation as an adjunct.

## A 1.2 INTELLECTUAL CAPITAL VULNERABILITY.

The candidate argues that the issue of intellectual capital is central to the sustainability of lean enterprises, which has implications for potential market disruption, the dispersal of intellectual capital and the supply chain's market leverage.

### A. 1.2.1 Market disruption.

The candidate has argued in this dissertation that enterprises centred on the exploitation of aging technological paradigms are vulnerable to disruptive technologies that originate outside of the enterprise. Moreover, the exploitation of aging paradigms can be regarded to result in diminishing returns and synergies from the effort expended (Schmenner and Swink, 1998, p. 110).

### A 1.2.2 Design capability dispersal.

Toyota proper adds only 15-25% of the total value in its supply chain value streams (Hines, 1996, p. 6; Hines, 2002, pp. 67-76). Toyota's low value-add percentage allows it to concentrate on the final assembly of supplied sub-assemblies and components from its supply chain (Kamath and Liker, 1994). Here, the candidate contends that two issues may arise from the implementation of LM, which centre upon tier 1 suppliers. The first issue is a potential negative supply chain perception of its role, which can be managed according to the methods and tools that were defined in Chapter 8 of this dissertation. The second issue is intellectual capital know-how and ownership, which may not be able to be managed in the case of market disruption.

**Production buffer.**

The candidate argues that Toyota behaves according to Ford's process conveyor for two reasons. Firstly, Toyota regulates production flow in the same manner that Ford's assembly conveyor did. Secondly, the isolated islands of manufacturing that are present in MP have been replaced effectively by external value streams. A fundamental difference between Ford's MP and Toyota's flow is that Toyota strives to synchronise its external value streams with final assembly through pull-production whereas Ford did not synchronise manufacturing with final assembly through pull-production. Here, the candidate argues that for this reason Toyota's tier 1 suppliers act effectively as a decoupling point in the responsibility for JIT flow. Hines explains that tier 1 suppliers are a critical interface between the parent and lower supply chain echelons. Tier 1 suppliers play a pivotal role as systems developers through their coordination and development of lower tier suppliers into a seamless value stream (Hines, 2002). The candidate contends that an issue that may arise is that tier 1 suppliers can regard themselves as a production buffer for their customer. Johnson *et al*. capture cynically the potential negative perception of suppliers as the customer "shifting their manufacturing problems and inefficiencies to the supplier" (Johnson *et al*., 2007, p. 44).

**Intellectual capital know-how and proprietary.**

Toyota's tier 1 suppliers play a significant role in product development, in addition to production supply (Hines, 2002). Toyota contrasts 1926 Ford, which relied heavily on in-house capabilities in the generation of intellectual capital. Kamath and Liker explain that Toyota employs typically between 100 and 200 tier 1 suppliers who engage in sub-assembly and component design, development and validation (Kamath and Liker, 1994). Here, the candidate argues that Toyota's concentration on final assembly and the leveraging of its suppliers' capabilities has the outcome of dispersing design capability downwards throughout the supply chain. Furthermore, the dispersal of design capability results largely in the surrendering of intellectual capital ownership upwards throughout the supply chain. Kamath and Liker explain that despite the significant number of tier 1 suppliers that Toyota employs, only approximately 5 to 10% enjoy the status of black-box suppliers, which Toyota calls partners. A key factor in the achievement of black-box status is the supplier's bargaining power, size and global standing. Non-partner suppliers are characterised by grey-box design status (Kamath and Liker, 1994, pp. 156-157). The candidate has argued in Chapter 8 of this dissertation that black-box supply reflects a dominant position in intellectual capital ownership by the supplier whilst grey-box design represents shared intellectual property. Whilst grey-box design represents a partnership in the ownership of intellectual capital, the candidate argues that Toyota uses its bargaining power, size and global standing to secure intellectual capital for its own advantage for three key reasons. Firstly, Toyota retains and does not divulge key intellectual capital to its supply chain. According to Womack *et al*. (1991, p. 147): "the lean assembler (Toyota) doesn't delegate to the supplier the detailed design of certain parts considered vital to the success of the car, due either to proprietary technology or to the consumer's perception of the product". Secondly, Toyota accumulates actively its suppliers' intellectual capital. According to Liker (2004, p. 208): "Toyota want to learn from suppliers, but never transfer all core knowledge or responsibility in any key area to suppliers". Moreover, according to Womack *et al*. (1991, p. 149): "obviously for the lean approach to work, the supplier must share a substantial part of its proprietary information about costs and production techniques" and that "the assembler (Toyota) and the supplier go over every detail of the supplier's production process". Thirdly, Toyota may exploit its suppliers' intellectual capital. According to Womack *et al*. (1991, p. 150): "by agreeing to share the profits from joint activities and letting suppliers keep profits from additional activities they undertake, the assembler (Toyota) relinquishes the right to monopolize the benefits from the supplier's ideas, benefits Western suppliers would be horrified to give up".

The candidate contends that Toyota's supply chain develops know-how but surrenders the proprietary ownership of its intellectual capital. Capability in intellectual capital is dispersed downwards throughout the supply chain whilst the leverage from intellectual capital is surrendered upwards throughout the supply chain.

### A 1.2.3 Market leverage.

The candidate argues in this section how Toyota may exploit its bargaining power over its suppliers and how this may undermine Toyota and its collective supply chain in the long-run.

**Toyota's sources of bargaining power over its suppliers.**

The candidate argues that Toyota has inherent bargaining power over its suppliers, which is an outcome from the general context of the automotive industry, Toyota's *keiretsu* system and its hierarchy of supplier recognition.

***General context of the automotive industry.***

Dorf and Byers applied the 6[142] forces model to evaluate the general competitive positions of producers and suppliers in the LM dominated era of the automotive industry. The results highlight intense competition between incumbent producers. Consumers have high bargaining power and the supplier's bargaining over its producers is modest (Dorf and Byers, 2005, Chapter 4). The LM era of the automobile paradigm's technological trajectory can be regarded to constitute an oligopolistic stabilisation of its market (Dosi, 1982, p. 147). Oligolopolistic stabilisation allows incumbent producers to leverage their bargaining power over their suppliers in order to lower the producer's costs (Schilling, 2005, p. 79).

***The keiretsu system.***

The Toyota enterprise is modelled on the Japanese *keiretsu* system, which is described as an affiliate organisation (Monden, 1993, p. 16), vertically integrated supply chain (Womack and Jones, 2003. p. 349; Schonberger, 2007, p. 403; Morgan and Liker, 2006, p. 182), system of supplier management (Browning and Heath, 2009, p. 26), set of interlocking corporations (Liker, 2004, p. 208) and an association of partner companies (Mika, 2006, p. 158). Liker and Choi (2004, p. 106) describe *keiretsu*s as: "close-knit networks of vendors that continuously learn, improve, and prosper along with their parent companies". A *keiretsu* is characterised by financial cross-investment and equity

[142] The 6 forces model is an extension of Porter's 5 forces model by the inclusion of the bargaining power of suppliers (Porter, 1980 cited in Porter, 1991, p. 101).

interlocking (Womack and Jones, 2003, p. 349), which includes long-term investment securities, investment stocks, bonds, contributions and loans (Monden, 1993, p. 16). Furthermore, *keiretsu*s include frequently financial institutions such as banks, insurers and traders (Womack et al., 1991, p. 192). A key outcome from *keiretsu*s is that individual companies own effectively a portion of each other, which creates reciprocal obligation and a collective financial future that motivates collaborative effort in order that "everyone should win" (Osono *et al*., 2008, p. 129). *Keiretsu*s strive for long-term and stable relationships (Monden, 1993, p. 16), which afford suppliers significant competitive advantages through efficient production, distribution, logistics, transportation systems, production responsiveness, information communication and customer relationships (Wu, 2003). Suppliers in a *keiretsu* are regarded as the "extended family" of the parent enterprise (Liker, 2004, p. 202), which allows the development of a focused manufacturing network (Browning and Heath, 2009, p. 26). Suppliers within *keiretsu*s accept contractual encumbrances that limit whom they may share intellectual capital with and whom they may do business with, which is in exchange for guaranteed business (Morgan and Liker, 2006, p. 182). Toyota's strong brand, market share and image of manufacturing excellence allow it to adopt a technological leader strategy and leverage monopolistic advantage over its supply network (Gemunden and Heydebreck, 1995, pp. 835-836).

The potential for Toyota's exploitation of its power advantage over its suppliers was recognised formally by Japanese parliament when House of Representatives member Michicko Tanaka questioned Premier Takeo Fakuda about Toyota's methods[143] in 1977: "Toyota Motor Company, Ltd, has earned the current profit of 210 billion yen. Behind this huge profit how many subcontractors (suppliers) have dropped tears? Toyota's completely rationalised production system strictly instructs its subcontractors to deliver the required parts within today or by tomorrow. Therefore, there is no excessive parts inventory at Toyota, and thus there is no warehouse and no sleeping funds invested in the inventory. However, subcontractors are in a precarious position if they occupy positions as low as the 3rd, 4th or 5th steps (tiers) in the vertical line among manufacturers. The reason is if they can not deliver their parts just in time for the needs of the paternal company, the contracts will be cancelled". Tanaka continues: "Moreover, a serious matter which can not go unnoticed is that this Toyota system is now prevailing among many industries and a vast number of subcontractors are likely to fall victims to this system. If this practice of bullying the subcontractors is left unrestricted, the Japanese economy will be thrown into chaos" (Tanaka, 1977 cited in Monden, 1993, p. 47). Tanaka's criticism prompted a response from Premier Fukuda: "The government will also give assurance that the paternal manufacturer will not force its rationalisation at the sacrifice of the subcontractors interest. This is my conviction" (Fukuda, 1977 cited in Monden, 1993, p. 48). Consequently, the Subcontractor's (supplier's) Law and the Anti-Monopoly Law were enacted, which resulted in the regulation of parent producers by the Japanese Government Fair Trade Commission

[143] The original transcript is Proceedings at the Japanese House of Representatives, No. 4: October 7, 1977, pp. 63-65.

(Monden, 1993, p. 48). A specific outcome was noted by Monden (1993, p. 49): "The *kanban* delivery system should not be forced on the supplier".

***Hierarchy of supplier recognition.***

Toyota's supply chain is characterised by heirachical[144] recognition of its suppliers. According to Kamath and Liker (1994, p. 156): "not all suppliers are equal". Here, the candidate argues that Toyota may maintain bargaining power over its suppliers through a hierarchical recognition, which accords with the relative bargaining power of Toyota's suppliers. According to Morgan and Liker (2006, p. 199): "even when trust is established, there is still clear difference between being inside and outside of Toyota, and Toyota always reserves the right to keep core technical competence to engineer and build key components in-house".

**Convergence of negative forces.**

The candidate argues that when an exploitative enterprise beholden to an aging technological paradigm is threatened with disruption then its parent and supply chain enterprises are beset with a negative convergence of market forces.

According to the general market context, the parent is at its weakest position of bargaining power relative to its consumers whilst the parent's suppliers are at their weakest position of bargaining power relative to their parent enterprise. Furthermore, if the supply chain disintegrates then the parent can be left holding obsolete intellectual capital without the know-how of its potential overspill to other applications, whilst a supplier can be left with competency-destroyed know-how that it is obliged contractually not to supply other customers.

## A 1.3 DISRUPTED SUPPLY.

JIT supply is vulnerable inherently from supply disruption, which may occur from uncontrollable external events or from unintended internal consequences. The proliferation of global JIT supply chains was identified by the Royal Society in 2010 as an emerging global risk, which is characterised as a collective rather than localised issue (Scientific Horizons Lecture 2, 2010).

### A 1.3.1 Safety buffer.

The concept of bufferless supply in LM flow drives out safety buffers in the value chain, which places great emphasis on the prevention of disruption. Whilst lean manufacturers apply rigorous preventative measures, supply disruption has numerous potential sources within the enterprise. *E.g.* scheduling failure, supplier defaults, staff turnover/training, union action, contract disputes, raw

[144] Toyota's hierarchical recognition of its suppliers from top to bottom is: Partner (full service provider), Mature (full system suppler), Child (being groomed for elevation) and Contractual (capability extender) (Kamath and Liker, 1994, p. 158).

material fluctuations in price/quality/availability, customer interjection, communication failure, machine and tooling breakdown *etc*. Furthermore, JIT flow is vulnerable to uncontrollable external events.

**Vulnerability to uncontrollable events.**

Although LM utilises comprehensive preventative measures and controls, it is vulnerable to uncontrollable events. Waller reported how an earthquake in Japan completely shut down Toyota Japan in 1995 and affected hundreds of associated companies[145]. Similarly a key supplier to Toyota was affected by fire in 1997, which created disarray[146] at an importune time (Waller, 2003). A contemporary example of interruptions to global lean supply chains is the April 2010 disruption to air travel through airborne ash from an erupting Icelandic volcano. Multiple supply chains were disrupted severely through failed components supply (The World Today, 2010 [radio broadcast] ABC, 891 South Australia, 19 April 2010 12.00 to 12:30 CST). The candidate argues that mass producers are better positioned to cope with uncontrollable events because of their inventory buffers.

### A 1.3.2 Supplier dual sourcing.

A key element in collaborative supply chain partnering within a LM enterprise is the expression of trust and commitment through the reward of long-term and exclusive supply contracts. Womack *et al*. contend that LM replaces the aggressive bidding and information withholding that is inherent in MP with constructive cooperation and reward through open negotiation (Womack *et al*., 1991, pp. 139-146). The candidate argued in Chapter 8 of this dissertation that the logical conclusion is to single-source supply in order to eliminate aggressive bidding and information withholding. However, single-sourcing increases dramatically supply disruption risk because of the absence of viable sourcing options. Yu *et al*. explain that multiple-sourcing reduces the probability of failure from supply disruption (Yu *et al*., 2009, p. 791). Furthermore, Sharma explains that multiple-sourcing can be used to introduce competition between suppliers (Sharma, 2010, p. 148).

**Competitive sourcing.**

Toyota seldom source from single suppliers. Toyota source typically 2 or 3 suppliers per component type and the suppliers bid competitively for a contract as new automobile models are introduced. The compensation to Toyota's suppliers for having to bid competitively is that successful bidders are awarded 100% supply for the given automobile model (Hines, 1996, p. 4; Liker and Choi, 2004, pp. 107-110; Morgan and Liker, 2006, pp. 182-183). *E.g.* Toyota may have three seat suppliers that

[145] Ironically, a 1923 earthquake in the Tokyo area resulted in the importation of thousands of Model T Ford trucks to replace destroyed transportation networks and distribute much needed supplies (Editor, 1988 cited in Ohno, 1988, p. 132). Toyota Japan was again disrupted by an earthquake and tsunami in April 2011, which affected Toyota Australia and its domestic suppliers.

[146] Toyota's sole-supplier for brake fluid valves suffered significant fire damage. Although initial disruption was estimated at two weeks shut-down at Toyota, collective crisis measures spared the full catastrophe (Yu *et al*., 2009, pp. 788-791).

supply simultaneously seats to different automobile models. Here, the candidate argues that Toyota is able to secure the benefits from supplier competition and manage supplier turnover through automobile models. Swink and Zsidisin suggest that multiple-sourcing provides the parent enterprise two benefits. Firstly, the parent is not held captive by a restricted supplier database. Secondly, competitive bidding stimulates performance improvement in long-standing suppliers and may prevent performance deterioration through stagnation and complacency (Swink and Zsidisin, 2006, p. 4232-4234). According to Liker and Choi, Toyota frame competitive bidding between its suppliers as a positive outcome because it provides suppliers an opportunity to improve themselves and in doing so secure potentially guaranteed supply contracts with an industry incumbent (Liker and Choi, 2004, pp. 107-110).

The candidate suggests that whilst Toyota demands loyalty from its suppliers, Toyota's practice of multiple-sourcing and competitive bidding may create a perception of non-reciprocated loyalty amongst suppliers.

## A 1.4 SYSTEMIC DYSFUNCTIONALITY.

LM is advocated frequently as a representation of best practice that has universal application (Sousa and Voss, 2008, p. 697). However, LM is also criticised for its universality (*e.g.* James-Moore and Gibbons, 1997; Cooney, 2002). The candidate has shown in this dissertation that LM is a dominant manufacturing paradigm when LM is employed as a primary business model under the appropriate contextual conditions. The candidate argues in this section that piecemeal application of LM can result in fragmented systems, agendas and mindsets, which are dysfunctional.

### A 1.4.1 Strategic disparity.

The candidate agrees with the LM researchers who contend that an enterprise approach to LM should be adopted rather than a tool-based or piecemeal approach to LM (*e.g.* Hines *et al*. 2004: Hines *et al*., 2008).

The candidate argues that a tool-based or piecemeal approach to LM can result in fragmented and potentially dysfunctional systems, which are characterised by strategic disparity in the objectives of the enterprise's core functions and processes.

### A 1.4.2 Employee and supply chain resistance.

Klein and Cusumano argued that the responsibility LM places on employees and supply chains for continual improvement, teamwork, multi-skilling, problem solving, self-management and continual personal development in an environment of bufferless[147] flow increases significantly worker job

[147] Whist there may be no inventory buffer in LM, mature lean practitioners warn of pushing operators beyond 85% of their maximum pace because errors will arise, which affect flow, productivity, quality and health (Ortiz, 2006, p. 49 and p. 203).

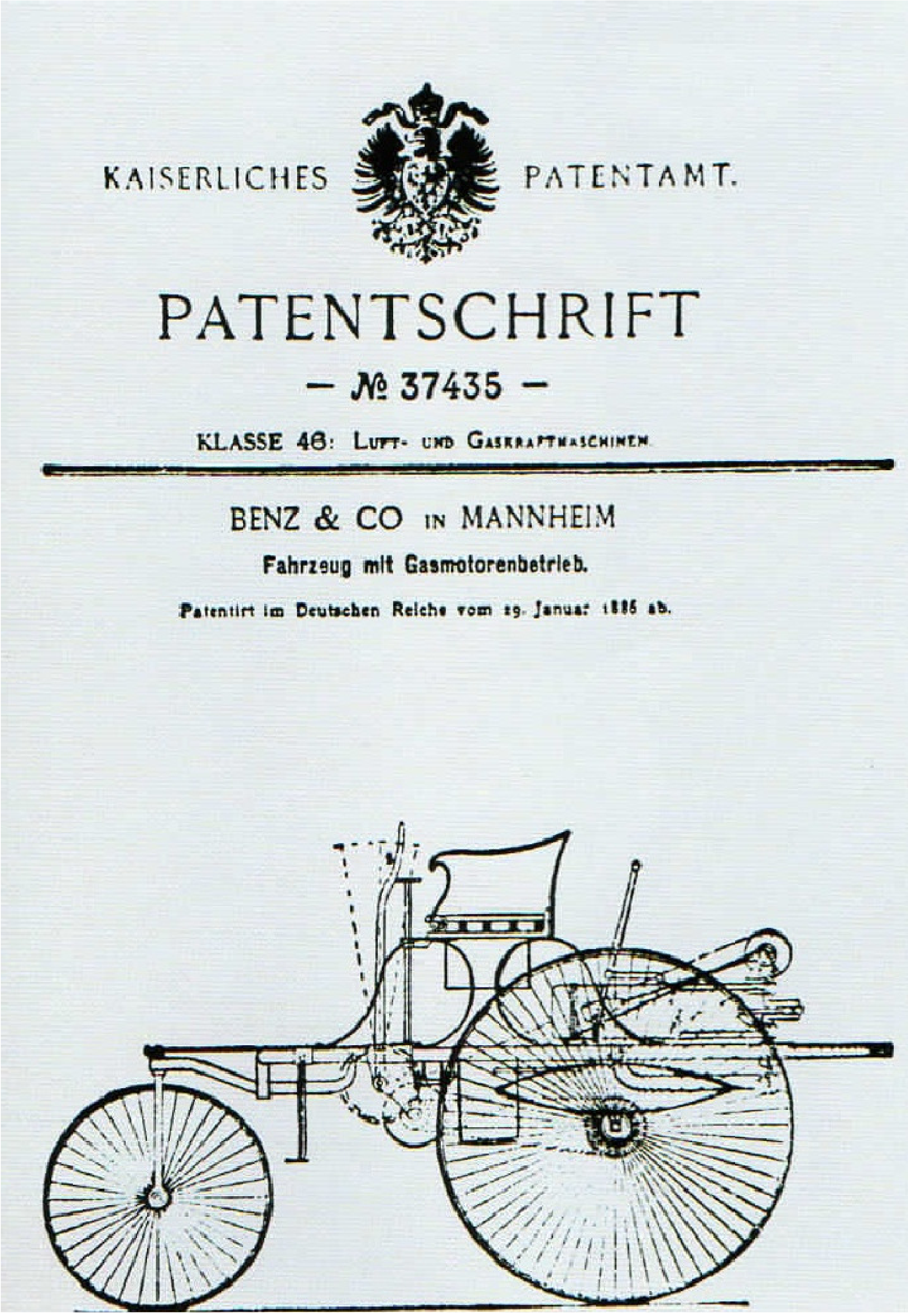
stress (Klein, 1989; Cusumano, 1994). Here, the candidate contends in light of the proactivity dilemma that the arguments of Klein and Cusumano were centred on the experiences of LM imitators in a Western context, which may have imposed LM principles without a complete understanding of the time and development required in order to develop a functional LM culture. Conti *et al*. researched the effects of LM on worker job stress and found that LM is not inherently stressful *per se* (Conti *et al*., 2006, p. 1032).

The proactivity dilemma contends that the implementation of LM in the absence of an appropriate proactivity propensity can provoke resistance towards LM in employees and suppliers.

**A 1.5 SUMMARY.**

The candidate presented in this section potential problems that may be encountered by enterprises that attempt the implementation of LM. The problems presented were the candidate's contentions and were formulated during the course of this dissertation as an adjunct.

## APPENDIX B
## PATENT FOR THE FIRST PRACTICAL AUTOMOBILE.



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KLASSE 46: LUFT- UND GASKRAFTMASCHINEN.

BENZ & CO IN MANNHEIM

Fahrzeug mit Gasmotorenbetrieb.

Patentirt im Deutschen Reiche vom 29. Januar 1886 ab.

*"Horseless carriage"*
*Coversheet of patent awarded to Karl Benz in 1886*
*for the first practical automobile.*